Agenda Item #7

EVALUATION OF PUGET SOUND FREEWAY HOV LANE HOURS OF OPERATION DEMONSTRATION: INITIAL RESULTS

BRIEFING PAPER
Prepared for the
December 2003 Transportation Commission Meeting

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PURPOSE:

Update the Commission on the Puget Sound High Occupancy Vehicle (HOV) Lane Hours of Operation Demonstration Project.

ACTION/OUTCOME:

The Commission will be briefed on implementation of the demonstration project and the initial results from the ongoing project evaluation. No action is requested at present.

BACKGROUND:

The performance of the Puget Sound region freeway HOV lanes was documented in an extensive study conducted in 2002 and completed in early 2003. The study found that I-405 and other eastside freeways had surplus HOV lane capacity after 7:00 p.m., and that in some instances, allowing general purpose traffic to use this capacity had the potential to improve traffic flow.

Pursuant to the study findings, the Commission directed the department to implement a two-year demonstration project to open HOV lanes on freeways east of Lake Washington (I-405, I-90, SR 520, and SR 167) to general purpose traffic between the hours of 7:00 p.m. and 5:00 a.m. This change in operating policy is in effect on designated segments of the HOV system seven nights per week. The demonstration project is designed to determine whether the revised policy has an impact on traffic speed, volume, safety, and HOV lane use relative to general purpose lane use.

The department proceeded with implementation of the demonstration project during the summer of 2003. This work, which was coordinated with FHWA and local jurisdictions, consisted of numerous safety and operational improvements including installation of guard railing, rumble strips, raised lane markings, and signage. These improvements

were constructed in June and July of 2003. The HOV lane operating polices were changed on each freeway segment as the improvements were completed.

DISCUSSION:

The Commission's direction called for periodic reports documenting performance of the HOV lanes. The presentation at the December Commission meeting is the first periodic report following implementation of the revised hours of operation. Information contained in this and subsequent reports will also be presented to the PSRC HOV Policy Advisory Committee.

The findings of the preliminary analysis, as contained in the attached Washington State Transportation Center (TRAC) report, can be summarized as follows:

- The percentage and number of single occupant (SOV) vehicles using the HOV lane after 7:00 PM has increased. This suggests that travelers are aware of the revised hours of operation.

- The change in HOV lane usage varies considerably from one location to another. SR 167 shows the most noteworthy increase, increases are insignificant in some locations.

- The change in SOV violations of the HOV lane during transition periods (6:45 PM – 7:00 PM, and after 5:00 AM) is generally small.

- Analysis of data from the initial months of revised HOV lane hours of operation does not show a significant change in HOV lane or general purpose lane speed. Congestion on the freeway system typically dissipates by 7:00 PM, therefore the comparatively modest changes in HOV lane volumes after 7:00 PM have not resulted in significant decreases in HOV lane speeds, or increases in general purpose lane speeds.

Analysis of accident data, and a survey of HOV lane users, will be presented to the Transportation Commission at a future meeting.

Upon completion of the demonstration project in 2005 a final report will be prepared. At that time Washington State Department of Transportation staff will obtain input from the PSRC HOV Policy Advisory Committee and the public. With this input a WSDOT staff recommendation will be presented to the Transportation Commission for consideration.

RECOMMENDATION:

None required at this time.

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Technical Working Paper

EVALUATION OF PUGET SOUND HOV LANE HOURS OF OPERATION: INITIAL RESULTS FOR TASKS 1 AND 2

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EXECUTIVE SUMMARY

Since its inception, the Puget Sound freeway high-occupancy vehicle (HOV) lane network has operated as an exclusive HOV-only facility, 24 hours a day, 7 days a week. In the summer of 2003, a two-year pilot program was begun to explore the potential costs and benefits of the use of the HOV lane network by single-occupant vehicles (SOVs) during particular times of the day on selected facilities, in an effort to maximize the use of existing facilities and enhance overall freeway network performance. Under this pilot program, the freeway HOV lane network is available for use by all vehicles, both HOVs and SOVs, during the hours of 7 PM to 5 AM, 7 days a week, on four of the five primary corridors in the region (I-405, SR 167, SR 520 east of I-405, I-90 east of Island Crest Way on Mercer Island). (Interstate 5's HOV lanes remain an exclusive HOV-only facility at all times). At all other times of the day (5 AM to 7 PM, 7 days a week), the entire Seattle-area freeway HOV lane network operates as an exclusive HOV-only system.

Initial weekday performance measurements were taken for the first two months of operation. Data examined included vehicle volumes, the share of vehicles in the HOV lane, vehicle speeds, the SOV violation rate in the HOV lane, and average car occupancy. Data were compared with the two months prior to the program start, as well as the same two months in 2002. Preliminary results are as follows:

SOV use of the HOV lane: SOV travelers appear to be taking advantage of the new hours of operation. The extent of use varies by location and time of day, with evening use being larger than morning use. There was generally a noticeable increase in the percentage and number of SOVs using the HOV lanes in the PM hours, and an increase in the share of all vehicles using the HOV lane after 7 PM.

HOV lane violation rates: Violations in the HOV lane (i.e., SOVs in the HOV lane from 5 AM to 7 PM) generally increased only slightly in the PM hours just before 7 PM. There was no significant change in violation rates during the AM hours.

Exceptions were on SR 167, particularly at the southbound end of the HOV lane network near Auburn, where violation rates have historically been high. At this location in the morning, violation rates actually improved after the new hours of operation went into effect, although they remain among the highest in the area. In the evening, violation rates worsened (from 16 to 25 percent of HOV lane vehicles), despite already being among the worst in the area.

Facility performance (speed and congestion): No significant overall changes in freeway performance were observed, though there were some indications of improvement on specific days. In general, congestion dissipated prior to the 7 PM start of the new HOV hours of operation, and thus changes in freeway operating speeds were marginal. Seasonal variations in roadway use and performance were often as significant as changes brought about by the revised HOV lane operating policy.

This is the first of three reports to be produced by this evaluation project. The preliminary results described in this paper are based on initial data collection only, and will be reviewed as additional data are collected in the coming months. The next report will be produced following the end of the first full year of operation in the summer of 2004.

SECTION 1
INTRODUCTION

This paper documents initial analytical results of a WSDOT-sponsored research effort to evaluate the effects of a pilot program to implement specific hours of HOV-only operation on selected corridors of the Seattle-area freeway HOV lane network. This document is organized as follows:

Introduction: An overview of the topics in this paper.

Background: A description of the research problem and the evaluation tasks being performed.

Methodology: A description of the data collection and analysis process used for evaluation tasks 1 and 2 (changes in vehicle occupancy and traffic flow, respectively).

General Observations: An overview of the initial results from evaluation tasks 1 and 2, with selected notable results from the data collected.

Summary of Preliminary Analysis: A summary of the preliminary results, based on the initial data collected thus far.

This paper is the first of a series of evaluation reports for this project, and describes results from a subset of the full evaluation effort (tasks 1 and 2 only), using initial data sets. Other components of the evaluation will be documented separately as those results become available.

SECTION 2
BACKGROUND

Since its inception, the Puget Sound freeway high-occupancy vehicle (HOV) lane network has operated as an exclusive HOV-only facility, 24 hours a day, 7 days a week. In recent years, discussions have taken place at the regional and state level regarding the potential use of the HOV lane network by single-occupant vehicles (SOVs) during particular times of the day or days of the week in an effort to maximize the use of existing facilities and enhance overall freeway network performance. In the summer of 2003, a two-year pilot program was begun to explore the potential costs and benefits of such a usage policy. Under this pilot program, the freeway HOV lane network is available for use by all vehicles, both HOVs and SOVs, during the hours of 7 PM to 5 AM, 7 days a week, on four of the five primary corridors in the region (I-405, SR 167, SR 520 east of I-405, I-90 east of Island Crest Way on Mercer Island). (Interstate 5's HOV lanes remain an exclusive HOV-only facility at all times). At all other times of the day (5 AM to 7 PM, 7 days a week), the entire Seattle-area freeway HOV lane network operates as an exclusive HOV-only system.

In association with this pilot program, an evaluation effort was developed to analyze the effects of this new policy. The focus of this effort is on the effects of the change in hours of HOV lane operation on freeway usage and performance, safety, and enforcement. The overall evaluation effort consists of six tasks:

1. **Car occupancy analysis**. The focus of this task is a review of changes in per-car occupancy, particularly in the HOV lane, and changes in the violation rate or SOV usage rate for the HOV lane during different times of the day. The Washington State Transportation Center (TRAC) at the University of Washington will perform this task.

2. **Traffic flow analysis**. This task involves an analysis of changes in freeway usage and performance in both the HOV and GP lanes. Principal measures include vehicle volumes, speeds, and congestion frequency. TRAC will perform this task.
3. **Safety evaluation**. WSDOT will evaluate incident and accident data to determine any changes in the number and frequency of those events during the revised HOV lane hours of operation.
4. **Enforcement evaluation**. WSDOT will summarize enforcement activities and analyze changes in HOV lane violation rates, based on WSP and HERO data. These results will also be compared with related data collected for task 1.
5. **Opinion Surveys**. WSDOT and TRAC will perform opinion surveys of the general public, public officials, and other stakeholders.
6. **Report Generation**. Periodic evaluation reports will be prepared by TRAC and WSDOT. These reports will summarize TRAC and WSDOT analyses for the tasks listed above.

The remainder of this paper will focus on the preliminary results **for tasks 1 and 2 only**. Other evaluation task results will be documented separately by TRAC and/or WSDOT as they become available.

INITIAL ACTIVITIES

The following activities were completed as part of this initial analytical effort for evaluation tasks 1 and 2:

- **Collect data**. Vehicle occupancy data were collected via direct field observations. The data were then processed, filtered, and archived in a

web-accessible database for subsequent analyses. Freeway usage data (primarily vehicle volumes and lane occupancy percentage) were collected by WSDOT from their sensor (loop) network. The data were then archived onto CD, for use with TRAC's software.

- **Compute performance measures**. Selected data sets for specific locations and time periods were extracted and processed to produce performance measures.
- **Analyze data for initial before/after comparisons.** Comparisons of freeway traffic characteristics before and after the revised hours of operation were implemented were made and analyzed. The "before" and "after" time periods were defined as the two months before and two months after the implementation time period, respectively. The implementation time period is the time during which the revised hours of operation were phased in across the four affected corridors.
- **Document initial results.** This paper documents the results based on the initial data collection effort.

SECTION 3
METHODOLOGY DESCRIPTION

The following is a description of the data collection process, data collection matrix, and computed performance measures being used to perform tasks 1 and 2 of this evaluation.

OVERVIEW OF THE DATA COLLECTION PROCESS

The following approach is being used to collect data for tasks 1 and 2 of this evaluation.

Task 1 data: Vehicle occupancy is being analyzed using data collected by a field data observer group. Each individual in the observer group collects data about the number of occupants per vehicle by direct visual observation, at selected locations and time periods throughout the central Puget Sound freeway network, and electronically records this information. This data collection effort is normally part of a separate WSDOT-sponsored project to monitor HOV lane network performance on an ongoing basis. The standard matrix of observation locations and times used by the observer group for their monitoring project has been supplemented with additional locations and times to support the HOV hours of operation evaluation effort, using supplementary support from WSDOT.

Task 2 data: Traffic flow analyses are performed using data collected by the WSDOT's embedded freeway sensor loop network. These data consist primarily of vehicle volumes and lane occupancy percentage values for each lane, at approximately 0.5 mile intervals, for 5-minute time periods, 24 hours a day, 7 days a week, throughout the freeway network. These raw data are archived by WSDOT. The data are then analyzed by TRAC using the capabilities of the TRAC-WSDOT FLOW analysis process. This process, developed over the last eight years by the Washington State Transportation Center through a WSDOT-sponsored research and development effort, uses TRAC-

developed software to compute detailed freeway performance measures from the freeway surveillance data collected by WSDOT's Northwest Region FLOW system.

Tasks 1 and 2 are both being performed by TRAC, in consultation with WSDOT staff, with data collection support from the staff of the HOV Lane Evaluation project and WSDOT Northwest Region.

DATA COLLECTION MATRIX

The general analytical approach for the initial phase of evaluation tasks 1 and 2 involves the analysis of vehicle occupancy data and sensor (loop) data for particular combinations of **location** (e.g., I-5 at milepost 170), **direction of travel** (e.g., northbound), **range of days** (e.g., July through September 2002, weekdays), **time period** (e.g., PM peak period from 5 PM to 7:15 PM), and **lane type** (GP or HOV). Ideally, one would want to analyze as many such combinations as possible, with dense geographic coverage of the freeway network. The primary practical limiting factor for the data collection process is the labor-intensive vehicle occupancy data collection effort, which requires human field observations and manual data collection. In contrast, the sensor loop data are generally available at locations throughout the freeway network. For that reason, the matrix of data collection measurements used in this project was constrained by the availability of vehicle occupancy measurements.

Figure 3.01 shows the location, times, and direction of travel of vehicle occupancy measurements taken during this initial evaluation process, along with the date of the start of revised hours of operation. Measurements were taken at eleven locations that were selected to sample each of the corridors affected by the revised hours of operation. For each location, efforts were made to collect data during both AM and PM peak periods (5-7 AM, 5-7 PM), with additional data collected from 7 PM to 7:15 PM, in both the GP and HOV lanes, and usually in both directions of travel.

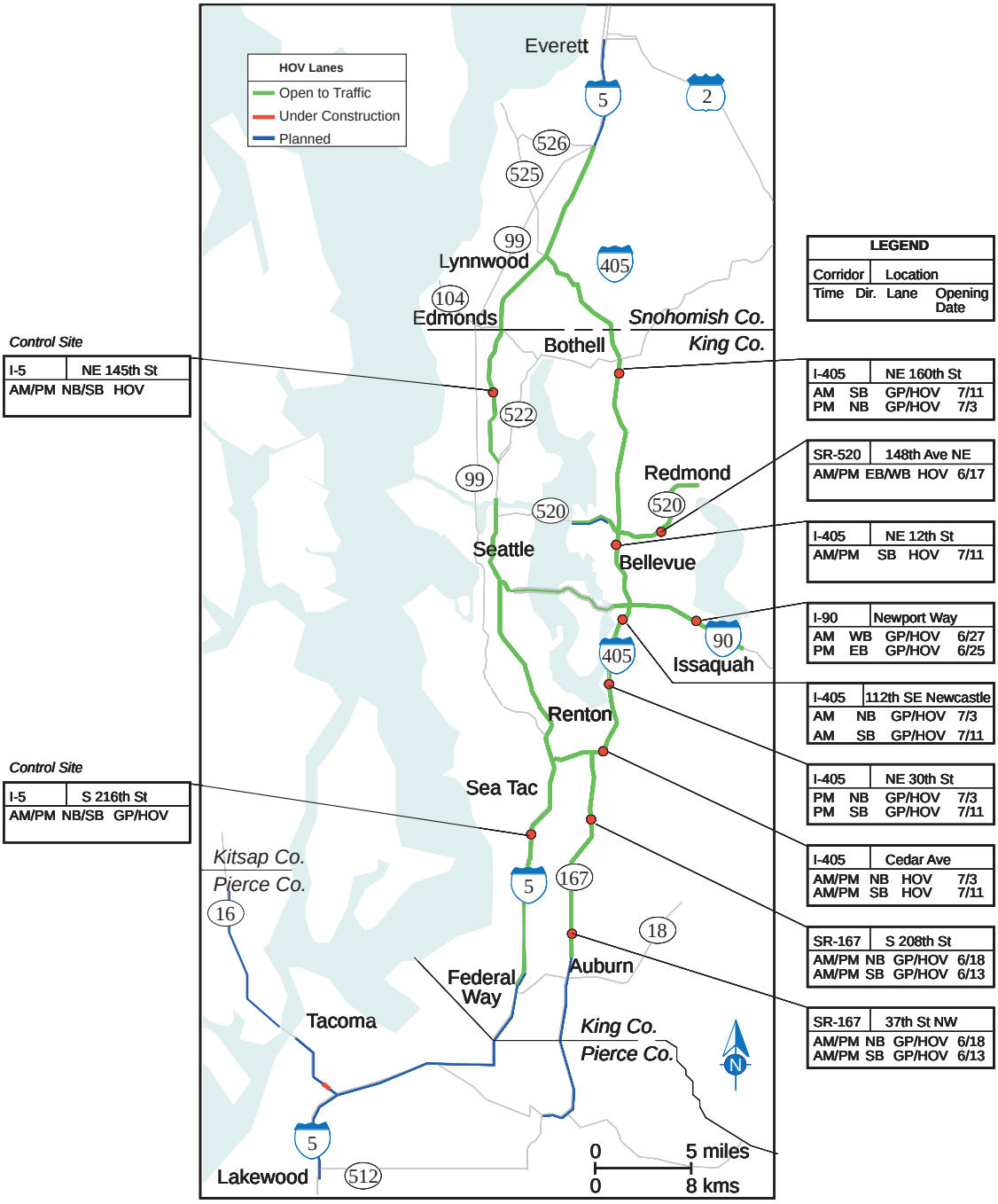

Figure 3.01. Measurement Sites

The result is 42 combinations of location, time, direction, and lane type. Multiple days of data collection were scheduled for each location, so that results could then be averaged. Measurements were made during both weekdays and weekends, though for this initial evaluation effort, only weekday data were processed.

For each measurement of average vehicle occupancy, matching traffic flow (loop) data were also extracted using the closest possible sensor location and time period.

PERFORMANCE MEASURES

The principal performance measures used in this initial evaluation were computed for each element (combination of location/time/direction/lane type) in the data measurement matrix. In general, individual observations are first averaged within each time period for each data collection day (e.g., 5-7 AM, 5-7 PM), and then averaged for longer time periods (e.g., the average of all "before" data collection days). The performance measures are as follows:

1. **Average car occupancy (ACO).** This performance measure summarizes the principal criterion for determining the eligibility of a vehicle to use the HOV lane. The unit of measure is **average number of occupants per vehicle**.
2. **SOV violation rate / SOV usage rate.** Individual field observations of vehicle occupancy were analyzed to determine the number and percentage of vehicles in the HOV lane that were below the usual minimum occupancy requirement. Because the HOV occupancy requirement is normally 2 persons or more, the unit of measure is **number or percentage of SOVs in the HOV lane**. Note that during the hours of 5 AM to 7 PM, this measure is considered a violation rate, while from 7 PM to 5 AM

(when all vehicles can use the HOV lane), it is considered an SOV "usage" rate.

3. **Average vehicle volume.** Volume data collected by sensor loops were processed and averaged for locations and time periods that match those of the vehicle occupancy data as closely as possible. Units of measure are **average number of vehicles per time period** (usually AM or PM peak period), **average number of vehicles per hour**, or **average number of vehicles per lane per hour**, depending on the type of analysis.

4. **HOV lane share**. Vehicle volume data for each lane at a location are processed to determine the percentage of all vehicles using the HOV lane. The unit of measure is **number or percentage of vehicles using the HOV lane**.

5. **Average 24-hour traffic profile.** While the measures listed above are aggregated across a time period, the average 24-hour traffic profile displays the time-varying characteristics of traffic at a location. These 24-hour graphs display the average vehicle volume, average estimated vehicle speed, and frequency of heavy congestion at 5-minute intervals throughout an average 24-hour day. Units of measure are **vehicles per hour, miles per hour,** and **likelihood (percentage) that heavy congestion occurs**, respectively, each of which varies by time of day. The averages are computed by processing all applicable days of sensor data for a given period of time (e.g., "before" or "after" weekday data).

6. **Day-to-day profiles.** Measures 1 through 4 can also be displayed as a graph of successive days to determine day-to-day variations, particularly

those days immediately before and after the hours of operation were implemented.

LIMITATIONS

Because of the limited time period for data collection since the start of the pilot project, before/after comparisons and observations are preliminary only. In addition, because of the labor-intensive data collection process for vehicle occupancy, the number of occupancy data measurements is limited. Sensor data can vary in quality as well.

SECTION 4
GENERAL OBSERVATIONS

The following is a summary of initial results for selected locations in the Seattle area freeway network. Unless otherwise noted, results are usually based on "before vs. after" comparisons, i.e., how did traffic characteristics change following implementation of the new HOV lane hours of operation. Before-and-after comparisons were based on two time periods: a "before" time period from April 12, 2003 through June 12, 2003, and an "after" time period from July 12, 2003 through September 12, 2003. These two-month time periods immediately precede and follow the one-month time period (June 13, 2003 through July 11, 2003) during which the phased introduction of the new hours of operation took place.

Measurements were taken at 11 freeway locations on SR 167, SR 520, I-90 and I-405 (the corridors affected by the new operations policy). Only weekday data were processed for this initial analysis.

NOTE: The following observations are based only on the initial data from the first two months of operation of the pilot project. Some before/after changes could also be attributable to factors other than the change in HOV lane hours of operation. Therefore, the following comparisons should be considered tentative, and subject to verification as additional data become available.

The following observations are grouped into three categories: changes in HOV lane use by SOVs, changes in occupancy compliance in the HOV lane, and changes in freeway performance.

HOV LANE USE BY SINGLE-OCCUPANT VEHICLES (SOVS)

The first set of observations focuses on changes in the use of the HOV lane following implementation of the new hours of operation.

1. Car occupancy data suggest that SOV travelers in the evening are utilizing the new hours of HOV lane operation, though the extent of use varies by location.

An analysis of per-car person occupancy in the HOV lanes after the revised hours of operation went into effect shows that shortly after the HOV lanes are opened to SOVs each weekday evening at 7 PM, the percentage of vehicles in the HOV lane that have one occupant (i.e., SOVs) increases, with the amount varying by location. Table 4.01 illustrates the change in the average percentage of SOVs in the HOV lane as time advances from the 6:45 PM-7:00 PM time period (only HOVs allowed) to the 7:00 PM-7:15 PM time period (all vehicles allowed). The SOV percentage in the HOV lane increased noticeably after 7 PM, with the largest increases on SR 167 southbound and on I-405 southbound near Newcastle. Increases were seen across all measured locations and travel directions. In contrast, this pattern was not seen during the "before" time period when 24-hour HOV–only access was in effect; during that time, the SOV percentage changed only slightly in most locations after 7:00 PM (exceptions were on SR 167 at Auburn, where SOV percentages have been unusually high in the past, and on I-405 southbound at Cedar Avenue, where a limited data sample was available).

In addition to observing a change in SOV percentage (7 PM-7:15 PM vs. 6:45 PM–7 PM) following the start of the pilot program, there was also a change in the resulting SOV percentage after 7 PM. A before vs. after comparison of the SOV percentage in the HOV lane during the 7:00 PM to 7:15 PM time period shows that the resulting average SOV percentage during that time period is usually at a higher level than before the start of the pilot program (see Table 4.01). For example, the percentage of

SOVs in the HOV lane after 7 PM on SR 520 at Overlake increased from 2.2 percent of all vehicles (before) to 12.5 percent (after) westbound, and from 5.7 percent to 12 percent eastbound. On southbound I-405 at Newcastle, the percentage of SOVs in the southbound HOV lane increased from 8.7 percent to 16.2 percent. On I-90 at Newport Way, eastbound traffic changed from less than 1 percent SOVs to 9.6 percent SOVs. The biggest changes were on SR 167, where in the northbound HOV lane, SOV traffic approaching Renton at S. 208th went from less than 1 percent to 14 percent, and southbound HOV lane grew from 2 percent SOVs to 31.7 percent SOVs. (On SR 167 in Auburn, southbound SOV traffic in the HOV lane went up from about 27 percent to 45 percent, though this is an area with traditionally high SOV rates in the HOV lane, while the percentage change was near zero at I-405 near Cedar Avenue based on limited data.)

Table 4.01. Percentage of SOVs in HOV Lane by Time of Day

			Before			After			After vs. Before
Corridor	Location	Direction	6:45-7:00 PM	7:00-7:15 PM	Change	6:45-7:00 PM	7:00-7:15 PM	Change	7:00-7:15 PM Change
I-405	NE 160th, Bothell	N	1.5%	1.5%	0.0%	1.8%	5.7%	3.9%	4.3%
I-405	NE 30th St, Newcastle	N	0.5%	0.5%	0.0%	3.0%	8.7%	5.7%	8.1%
I-405	Cedar Ave, Renton	N	1.2%	0.3%	-0.9%	0.9%	6.9%	6.0%	6.6%
I-405	NE 12th St, Bellevue	S	4.7%	3.4%	-1.3%	n/a	n/a		
I-405	NE 30th St, Newcastle	S	1.6%	8.7%	7.1%	1.5%	16.2%	14.7%	7.5%
I-405	Cedar Ave, Renton	S	1.8%	13.5%	11.7%	3.9%	13.2%	9.4%	-0.3%
I-90	Newport Way, Issaquah	E	0.7%	0.8%	0.1%	1.3%	9.6%	8.3%	8.8%
SR 167	S 208th St, Renton	N	2.6%	0.5%	-2.1%	5.5%	14.0%	8.6%	13.5%
SR 167	37th St. NW, Auburn	N	1.8%	1.0%	-0.8%	2.8%	10.4%	7.5%	9.4%
SR 167	S 208th St, Renton	S	2.4%	2.0%	-0.4%	8.4%	31.7%	23.3%	29.7%
SR 167	37th St. NW, Auburn	S	16.6%	26.9%	10.3%	25.5%	45.1%	19.6%	18.3%
SR 520	NE 148th, Redmond	E	3.8%	5.7%	1.9%	2.0%	12.0%	10.0%	6.3%
SR 520	NE 148th, Redmond	W	3.0%	2.2%	-0.8%	7.4%	12.5%	5.1%	10.2%

A result of these changes in SOV use in the HOV lane was that average car occupancy (ACO) in the HOV lane generally dropped after 7 PM following implementation of the new hours of operation (see Table 4.02). In some cases, the average car occupancy dropped below 2.0 (the minimum value expected when HOV-only usage is required). The most notable example is on southbound SR 167 at Renton (S. 208th), where the ACO dropped to just over 1.8. In several other cases, ACO dropped to

just under 2.0. (ACO dropped below 1.7 on SR 167 at Auburn, but this is an atypical case for reasons that will be described shortly.)

2. The increase in the percentage of SOVs in the HOV lane was accompanied by increases in the total HOV lane vehicle volumes during the 7:00 to 7:15 PM period (start of the new hours of operation), in most cases.

In addition to increases in the percentage of SOVs in the HOV lane as noted above, before/after comparisons during the 7-7:15 PM period show that total vehicle volumes consistently increased as well. See Table 4.02. Therefore, the increase in the percentage of SOVs in the HOV lane most likely corresponds to increased SOV volume, and not to a drop in the number of HOVs relative to the number of SOVs.

3. The percentage of all vehicles that use the HOV lane increased after 7 PM, but the magnitude varies noticeably by location.

The percentage of all vehicle traffic at a location that is using the HOV lane increased during the 7 to 7:30 PM time period following the implementation of revised hours of operation, but the amount varies considerably by location. See Table 4.03. SR 167, and I-405 between Renton and Bellevue, show the largest increases in vehicle use of the HOV lane after the 7 PM change in legal lane use. Note that a comparison of the same time periods in the year 2002 shows that the HOV lane's share of all traffic increased during that year as well without any revised hours of operation; however the magnitude of the 2002 change was smaller than the corresponding change in 2003.

Table 4.02. ACO and Vehicle Volumes in HOV Lane

			HOV Lane (7:00-7:15 PM)						HOV Lane (7:00-8:00 PM)				All Lanes Combined (7:00-8:00 PM)			
			ACO		2003 Vehicle Volume		Volume Change		2003 Vehicle Volume		Volume Change		2003 Vehicle Volume		Volume Change	
Corridor	Location	Dir.	(before)	(after)	(before)	(after)	(%)	(number)	(before)	(after)	(%)	(number)	(before)	(after)	(%)	(number)
I-405	NE 160th, Bothell	N	2.15	2.12	109	159	46%	50	366	537	47%	171	3817	4111	8%	294
I-405	NE 30th St, Newcastle	N	2.06	2.18	142	215	51%	73	526	789	50%	263	2826	3145	11%	319
I-405	Cedar Ave, Renton	N	2.17	2.18	130	205	58%	75	481	738	53%	257	3478	3889	12%	411
I-405	NE 12th St, Bellevue	S	2.13	n/a	128	170	33%	42	419	518	24%	99	4730	4903	4%	173
I-405	NE 30th St, Newcastle	S	2.09	1.99	203	317	56%	114	677	1035	53%	358	3536	3867	9%	331
I-405	Cedar Ave, Renton	S	2.06	1.99	147	259	76%	112	499	834	67%	335	3392	3776	11%	384
I-90	Newport Way, Issaquah	E	2.14	2.09	56	77	38%	21	181	248	37%	67	2908	2881	-1%	-27
SR 167	S 208th St, Renton	N	2.35	2.04	94	130	38%	36	349	478	37%	129	2243	2461	10%	218
SR 167	37th St. NW, Auburn	N	2.22	2.18	66	100	52%	34	240	366	53%	126	2026	2243	11%	217
SR 167	S 208th St, Renton	S	2.13	1.82	126	213	69%	87	462	752	63%	290	3132	3307	6%	175
SR 167	37th St. NW, Auburn	S	1.79	1.68	117	227	94%	110	416	783	88%	367	2901	3122	8%	221
SR 520	NE 148th, Redmond	E	2.11	1.99	51	68	33%	17	194	250	29%	56	1695	1745	3%	50
SR 520	NE 148th, Redmond	W	2.08	2.04	81	104	28%	23	276	357	29%	81	2210	2250	2%	40

Table 4.03. Share of Traffic in HOV Lane in Weekdays (7:00-7:30 PM)

Corridor	Location	Mile Post	HOV Share (Before)				HOV Share (After)				Change in HOV share			
			2003		2002		2003		2002		2003		2002	
			NB/EB	SB/WB	NB/EB	SB/WB	NB/EB	SB/WB	NB/EB	SB/WB	NB/EB	SB/WB	NB/EB	SB/WB
SR 167	S 208th St, Renton	22.92	15.8%	14.9%	16.2%	15.0%	19.7%	23.4%	16.7%	17.2%	3.9%	8.5%	0.5%	2.2%
SR 167	37th St. NW, Auburn	17.37	12.3%	14.5%	12.4%	16.4%	16.7%	26.1%	14.7%	19.0%	4.4%	11.6%	2.3%	2.6%
SR 520	NE 148th, Redmond	9.2	11.1%	12.6%	11.5%	11.4%	14.3%	16.0%	12.2%	12.8%	3.2%	3.4%	0.7%	1.4%
I-90	Newport Way, Issaquah	13.44	6.5%	8.5%	7.3%	9.1%	9.0%	10.7%	8.7%	10.5%	2.5%	2.1%	1.3%	1.3%
I-405	NE 160th, Bothell	22.46	9.9%	11.3%	10.1%	10.2%	13.7%	14.0%	11.7%	12.7%	3.7%	2.7%	1.6%	2.5%
I-405	NE 12th St, Bellevue	14.25	8.1%	9.4%	7.7%	9.2%	10.3%	12.0%	9.1%	10.5%	2.2%	2.6%	1.4%	1.3%
I-405	NE 30th St, Newcastle	6.52	18.8%	20.3%	19.4%	20.0%	25.5%	28.4%	22.1%	23.4%	6.7%	8.1%	2.8%	3.4%
I-405	112th SE, Newcastle	8.92	17.5%	20.5%	17.7%	20.1%	23.2%	28.9%	20.1%	24.2%	5.6%	8.4%	2.4%	4.1%
I-405	Cedar Ave, Renton	3.57	14.0%	15.8%	15.3%	16.6%	19.3%	24.2%	17.8%	24.4%	5.3%	8.5%	2.5%	7.9%

A notable example of a change in HOV lane usage during the initial period following the start of revised hours of operation was on SR 167. Tables 4.04 through 4.06 summarize the changes in traffic characteristics for one location on southbound SR 167, South 208th Street in Renton, during the evening peak period. Table 4.04 describes the average per-car person occupancy pattern before and after revised hours are put into place. Note that prior to the start of the pilot program, both GP and HOV vehicle occupancies were generally consistent for the three time periods shown (peak period of 5-7 PM, and the 15-minute time periods just before and after 7 PM), with little change from one time period to the next. In contrast, the vehicle occupancy pattern after the revised hours of operation began shows significant changes after 7 PM. In particular, the per-car person occupancy in the HOV lane drops from 2.11 before 7 PM, to 1.82 after 7 PM. (The fact that the ACO for the GP lanes increases from 1.2 to 1.40, would indicate that some of the HOVs previously in the HOV lane have now abandoned the HOV lane in favor of the GP lane, and thus the decrease in HOV lane ACO is not entirely due to just increased SOV volume in that lane.) A similar change is noted in the percentage of SOVs in the HOV lane. Prior to the pilot program, the SOV violation rate ranged between 1.6 and 2.4 percent between 5 PM and 7:15 PM; after the pilot program started, the SOV percentage averaged 2.4 percent for the entire 5-7 PM period, increasing to 8.4 percent just before 7 PM, then growing substantially to (a now legal) 31.7 percent just after 7 PM.

The changes in SOV percentage in the HOV lane were accompanied by changes in vehicle volumes as well. Table 4.05 summarizes the before/after comparisons of vehicle volumes for the GP lanes and HOV lane for the 7 to 7:30 PM time period, for both 2002 and 2003. The number of vehicles in the HOV lane grew by over 66 percent after the pilot program began. The analysis of 2002 data shows that seasonal differences alone suggest an expected increase of 19 percent. The rest of the 66 percent increase is

presumed to be the result of the new hours of operation policy. Meanwhile, the total (GP+HOV) directional roadway volume went up by over 5 percent. The share of all traffic using the HOV lane grew from 15 percent to over 23 percent for the same time period; this is also greater than one would expect from 2002 data. While this change in HOV lane use was occurring after 7 PM, it must be noted (as can be seen in Table 4.06) that while the HOV volume for the 5-7 PM peak period rose by about 10 percent after the start of the pilot program, this increase is actually less than the almost 14% growth observed during these same months the year before.

While volumes were increasing in the HOV lane, including a significant number of SOVs, the distribution of vehicles by lane also changed. For the two-month period following implementation of the revised hours of operation, Figure 4.01 shows the distribution of vehicles on each lane for the 6:30 to 7:00 PM time period for each weekday. Figure 4.02 shows the corresponding data for the 7:00 to 7:30 PM time period. A comparison of these graphs illustrates the increase in HOV lane use after 7 PM. (Note that there is also a definite day-of-week trend apparent in these graphs. The data shows a distinct increase in HOV lane use prior to 7 PM on Fridays. It is not clear from the current analysis if this is because of a greater number of HOV eligible vehicles (couples headed out together on Friday night), or whether it is caused by an increase in violations.) Overall, the average volume distribution for this location changed from 19%-42%-39% (left HOV lane, middle GP lane, and right GP lane respectively) to 23%-38%-39%. See Table 4.07.

Table 4.04. Changes in ACO (SR 167 SB at S. 208th St, Renton)

ACO (2003)	5-7 PM		6:45 to 7 PM		7 to 7:15 PM	
	Before	After	Before	After	Before	After
GP	1.22	1.20	1.20	1.19	1.22	1.40
HOV	2.18	2.17	2.21	2.11	2.13	1.82
SOV % in HOV lane	1.6%	2.4%	2.4%	8.4%	2.0%	31.7%

Table 4.05. Changes in Vehicle Volumes during 7-7:30 PM (SR 167 SB at S. 208th St, Renton)

Vehicle Volume (7-7:30 PM)	Total		GP		HOV		HOV Lane Share	
	2003	2002	2003	2002	2003	2002	2003	2002
Before	1664	1671	1416	1421	248	250	14.9%	15.0%
After	1757	1738	1345	1439	412	299	23.4%	17.2%
Volume change	93	67	-71	18	164	49		
%change	5.6%	4.0%	-5.0%	1.3%	66.1%	19.6%		

Table 4.06. Changes in Vehicle Volumes during 5-7 PM (SR 167 SB at S. 208th St, Renton)

Vehicle Volume (5-7 PM)	Total		GP		HOV		HOV Lane Share	
	2003	2002	2003	2002	2003	2002	2003	2002
Before	8220	8200	6725	6525	1495	1675	18.2%	20.4%
After	8160	8140	6520	6235	1640	1905	20.1%	23.4%
Volume change	-60	-60	-205	-290	145	230		
%change	-0.7%	-0.7%	-3.0%	-4.4%	9.7%	13.7%		

Table 4.07. Vehicle Volume Distribution (SR 167 SB at S. 208th St, Renton)

	6:30 - 7:00 PM		7:00-7:30 PM	
	Average Number of Vehicles	Average % of all Vehicles	Average Number of Vehicles	Average % of all Vehicles
L1 = right GP lane	735	38.9%	676	38.5%
L2 = left GP lane	801	42.3%	669	38.1%
HOV = inside HOV lane	357	18.8%	412	23.4%

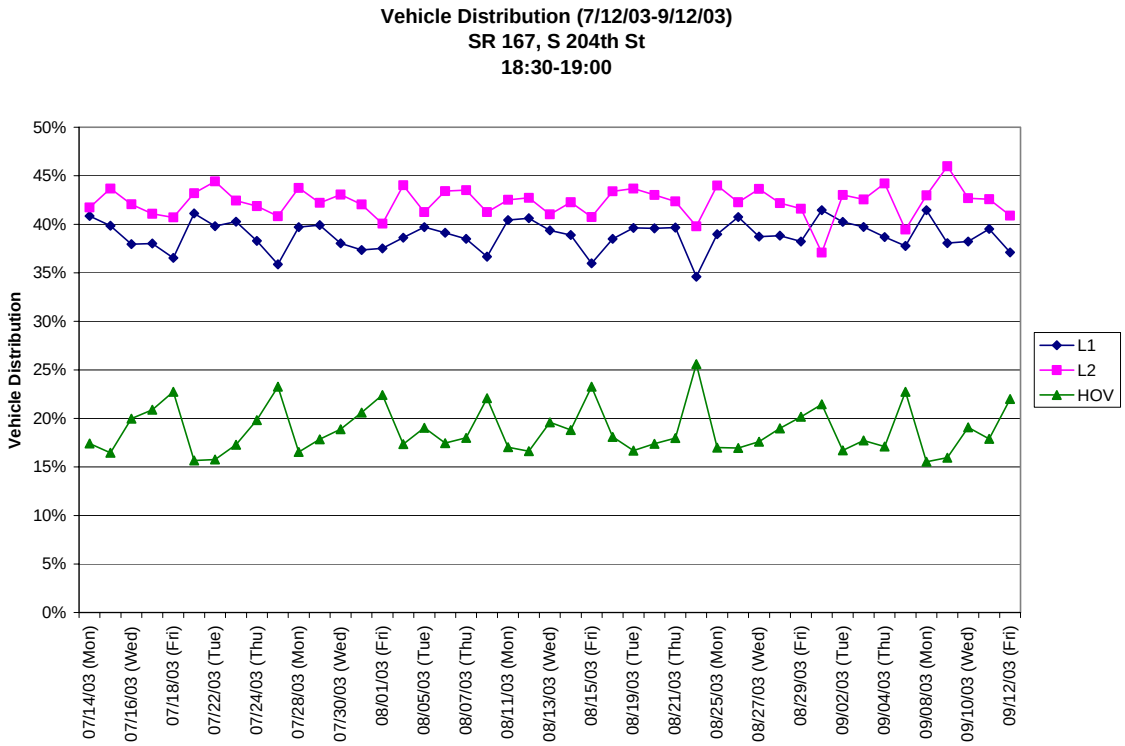

Figure 4.01. Distribution of Vehicles by Lane (6:30-7PM)

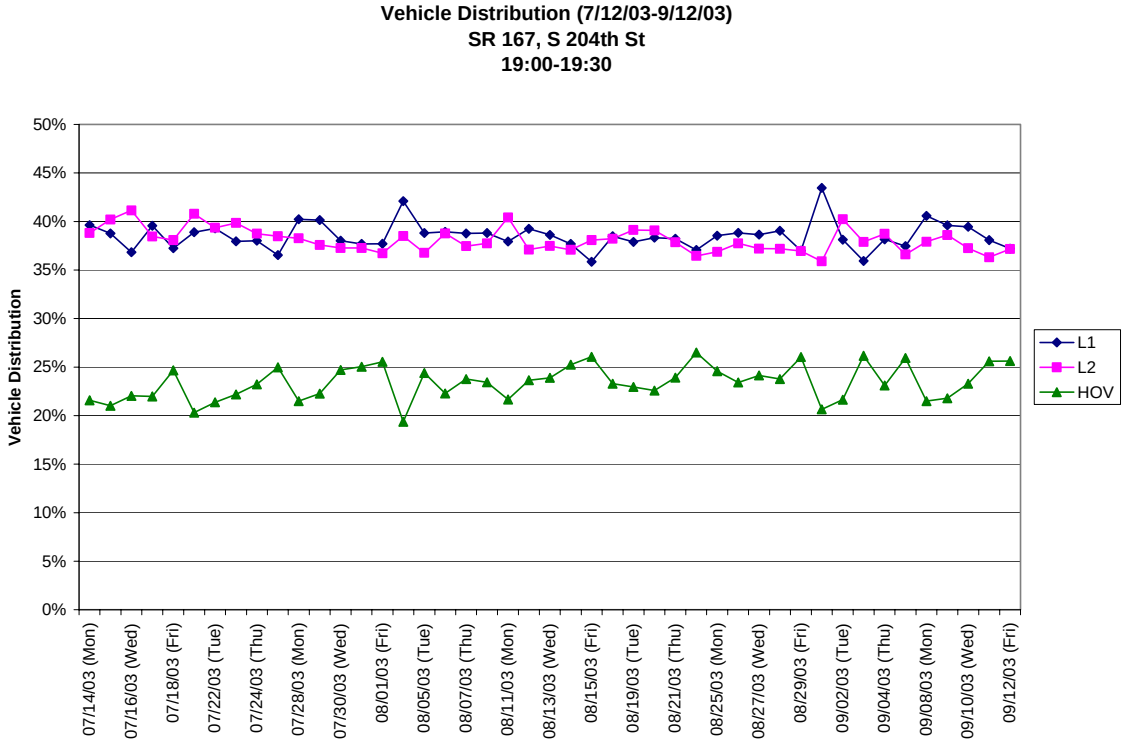

Figure 4.02. Distribution of Vehicles by Lane (7-7:30PM)

HOV LANE COMPLIANCE BY SINGLE-OCCUPANT VEHICLES

Another area of interest is the extent to which use of the HOV lane by SOVs is occurring during hours when the HOV-only policy is in effect (5 AM to 7 PM).

4. SOV violation rates during the PM shoulder period did not change significantly in most cases.

A before-after comparison during the time period leading up to the start of open access to the HOV lanes (6:45 to 7:00 PM) shows that the percentage of vehicles violating the HOV-only policy did increase somewhat, possibly in anticipation of the 7 PM start of general HOV lane use, though in most locations the difference was 3 percentage points or less (see Table 4.08). While the change was small (and often statistically insignificant) at most locations, eight of the 11 locations showed an increase in violations just prior to the 7 PM relaxation of the HOV eligibility rules.

The outliers to these general observations were SR 167 in Renton (southbound), where the SOV violation rate went from 2.4 to 8.4 percent, and SR 520 westbound at Overlake, where the SOV violation rate went from 3 percent to 7.4 percent.

The most significant exception to the pattern of SOV violation rates based on the data thus far is SR 167 southbound in Auburn in the evening transition period, with a 9 percent increase in the violation rate (from 16.6 to 25.5 percent). This location is near the edge of the HOV lane network (the HOV lane stops about one mile downstream from this site) and the direction of travel is outbound toward the end of the HOV network. Locations near the end of HOV facilities traditionally have the highest violation rates, as can be seen by the very high initial violation rate of over 16 percent at this site. Consequently, the fact that the largest increase in violations would occur at such a location is perhaps not surprising.

This result does highlight the concern expressed by some PSRC HOV Committee members prior to the demonstration project, that high violation rates tend to foster even

Table 4.08. SOVs in the HOV lane, AM and PM

PM			6:45-7:00PM		
Fwy	**Location**	**Dir**	**(before)**	**(after)**	**SOV Shift**
I-405	NE 160th, Bothell	N	1.5%	1.8%	0.3%
I-405	NE 30th St, Newcastle	N	0.5%	3.0%	2.5%
I-405	Cedar Ave, Renton	N	1.2%	0.9%	-0.3%
I-405	NE 12th St, Bellevue	S	4.7%	n/a	
I-405	NE 30th St, Newcastle	S	1.6%	1.5%	-0.1%
I-405	Cedar Ave, Renton	S	1.8%	3.9%	2.0%
I-90	Newport Way, Issaquah	E	0.7%	1.3%	0.7%
SR 167	S 208th St, Renton	N	2.6%	5.5%	2.9%
SR 167	37th St. NW, Auburn	N	1.8%	2.8%	1.0%
SR 167	S 208th St, Renton	S	2.4%	8.4%	6.0%
SR 167	37th St. NW, Auburn	S	16.6%	25.5%	8.9%
SR 520	NE 148th, Redmond	E	3.8%	2.0%	-1.8%
SR 520	NE 148th, Redmond	W	3.0%	7.4%	4.4%
AM			**5:00-7:00AM**		
Fwy	**Location**	**Dir**	**(before)**	**(after)**	**SOV Shift**
I-405	NE 160th, Bothell	S	2.5%	2.7%	0.1%
I-405	112th SE, Newcastle	N	5.6%	4.2%	-1.4%
I-405	Cedar Ave, Renton	N	2.6%	3.2%	0.6%
I-405	NE 12th St, Bellevue	S	4.4%	n/a	
I-405	NE 30th St, Newcastle	S	3.2%	3.3%	0.1%
I-405	Cedar Ave, Renton	S	1.3%	n/a	
I-90	Newport Way, Issaquah	W	5.3%	1.6%	-3.6%
SR 167	S 208th St, Renton	N	7.1%	2.6%	-4.5%
SR 167	37th St. NW, Auburn	N	5.1%	1.7%	-3.5%
SR 167	S 208th St, Renton	S	7.5%	4.5%	-3.0%
SR 167	37th St. NW, Auburn	S	25.6%	16.5%	-9.1%
SR 520	NE 148th, Redmond	E	1.4%	3.6%	2.2%
SR 520	NE 148th, Redmond	W	6.4%	7.3%	0.8%

more violations. That is, when violation rates are low, drivers are reluctant to violate because they stand out. But as violation rates increase, more and more drivers lose their reluctance to violate, thus dramatically increasing violation rates. The fact that the largest increase in violation rates occurs at the site which already had the highest violation rate prior to the demonstration tends to support this concern, and warrants additional study as the demonstration progresses.

5. SOV violation rates during the AM peak period did not change significantly in most cases.

A before-after comparison during the 5 AM to 7 AM time period (i.e., following the 5 AM resumption of HOV-only access) shows that the SOV violation rate either decreased or only increased modestly (less than 1 percentage point). In only one case (SR 520 at Overlake eastbound) did the violation rate increase by more than 1 percent (from 1.4 percent to 3.6 percent), while in several cases marked decreases in violation rates occurred. See Table 4.08.

Thus, unlike the PM period, the change in HOV lane access appears to have had a positive effect on HOV lane compliance in the morning.

GP AND HOV LANE PERFORMANCE

Data were collected to analyze the extent to which open access to the HOV lane during the revised hours of operation affected GP and HOV traffic performance.

6. Freeway performance generally did not change significantly, based on the initial data set.

In general, before/after comparisons based on the initial data set did not show a significant change in freeway performance at the measurement locations in terms of speed, volume, and frequency of congestion, around the time of day when the revised hours of operation go into effect (7 PM). Figures 4.03 through 4.28 show the GP and HOV performance graphs (overlaying before and after data) for each location. The

overall characteristics of the before and after patterns are usually similar to one another, though there can be differences depending on time of day.[1] A comparison of the patterns for the time period of particular interest, namely the PM peak period and the transition after 7 PM, shows that there were changes in usage (vehicle volume) in the HOV lane at some locations, consistent with the volume increases noted previously. Locations on SR 167 southbound showed the most notable change in freeway usage, primarily in the HOV volumes, which had a noticeable increase immediately after 7 PM; some locations on I-405 and SR 520 also showed smaller increases. However, associated differences in performance (average speed and congestion) after 7 PM were either not significant or inconclusive, based on the initial data.

7. There is not yet sufficient data to show how congestion at 7 PM is affected by the additional capacity from the HOV lane.

One potential benefit of the revised hours of operation was thought to be the ability to reduce the impact of congestion that had built up in the afternoon peak period and had not yet dissipated by 7 PM, by providing additional general purpose freeway capacity at that time via the opening of the HOV lane to all traffic. The performance profile graphs show that on average, however, congestion generally dissipates before 7 PM at the measurement locations, making it more difficult to determine the potential effect of the HOV lane opening.

On specific days when significant congestion does persist at 7 PM, the initial data are not yet conclusive in showing how congestion reduction is affected by the opening of the HOV lane to general traffic. For example, an analysis was performed at locations on

[1] Each figure displays two types of measures for each site: 1) a line curve showing average total vehicle volume by time of day, on an equivalent per-hour basis (use the vehicles/hour scale on the left axis of the figure) and 2) a graph showing the likelihood of encountering congestion (use the 0 to 100 percent probability scale on the right axis). The color lines are "before" conditions, while the black lines are "after" conditions. In addition, the "before" volume curve shows the average approximate "before" speed condition by time of day, using green for 55 mph and above, yellow for 45 to 55 mph, and red for less than 45 mph.

SR 167 and on I-405 for selected days before and after the start of the new hours of operation that showed congestion during the PM peak period around 7 PM, to analyze any differences in the dissipation of that congestion. See figures 4.29 through 4.34. At a location on SR 167 (southbound at 43rd Street SW near Renton), performance profiles were produced for May 30, 2003 ("before" time period) and August 8 and 22 ("after"). The May 30 profile shows congestion (yellow and red graphs) in the GP lane approaching 7 PM, with reduced congestion after 7 PM. On August 8 and 22 ("after" period), congestion also exists approaching 7 PM, but dissipates quickly after 7 PM. At a location on I-405 (southbound at NE 14th approaching Bellevue), profiles were produced for May 6 and 20 ("before") and July 24 (after). Results show that on the "before" days, congestion dissipated quickly on May 6, with some lingering congestion after 7 PM on May 20, and quick dissipation of congestion at 7 PM on the "after" day. In each case, congestion dissipates after 7 PM, though the speed of the congestion dissipation varies somewhat. While the revised hours of operation could be having some effect on congestion dissipation, the extent to which general access to the HOV lane enables this dissipation cannot be determined from the limited initial data set. Additional data are required to analyze the frequency and magnitude of any congestion reduction benefit.

8. Normal background seasonal variations can be significant.

The analyses of before/after changes assume that, all else being equal, the revised hours of operation are the only factor that might produce significant changes in traffic characteristics between the before and after time periods. However, there is another potentially influential factor, namely seasonal variations that occur regardless of changes in the hours of HOV lane operation. Since the before time period corresponds to mid- to late spring when school is still in session, while the after period corresponds to mid- to late summer, when school is generally not in session and vacation travel is more common, it is not surprising that these two time periods might have different traffic and

congestion patterns, independent of the hours of HOV lane operation. Because of the potential magnitude of these seasonal differences, it is important to take that factor into account when analyzing the effects of the revised hours of operation. For that reason, 2002 ACO and volume data were sometimes used for comparison in this paper. As additional data are collected, these seasonal variations can be further analyzed.

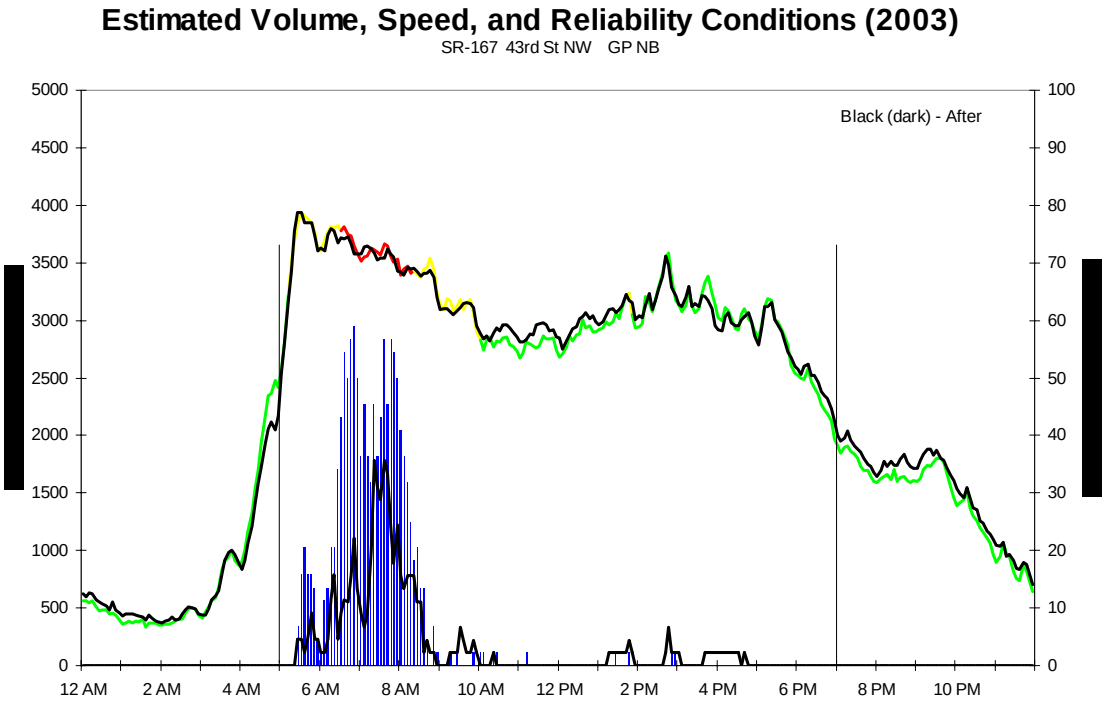

Figure 4.03. SR 167 NB near Auburn, GP

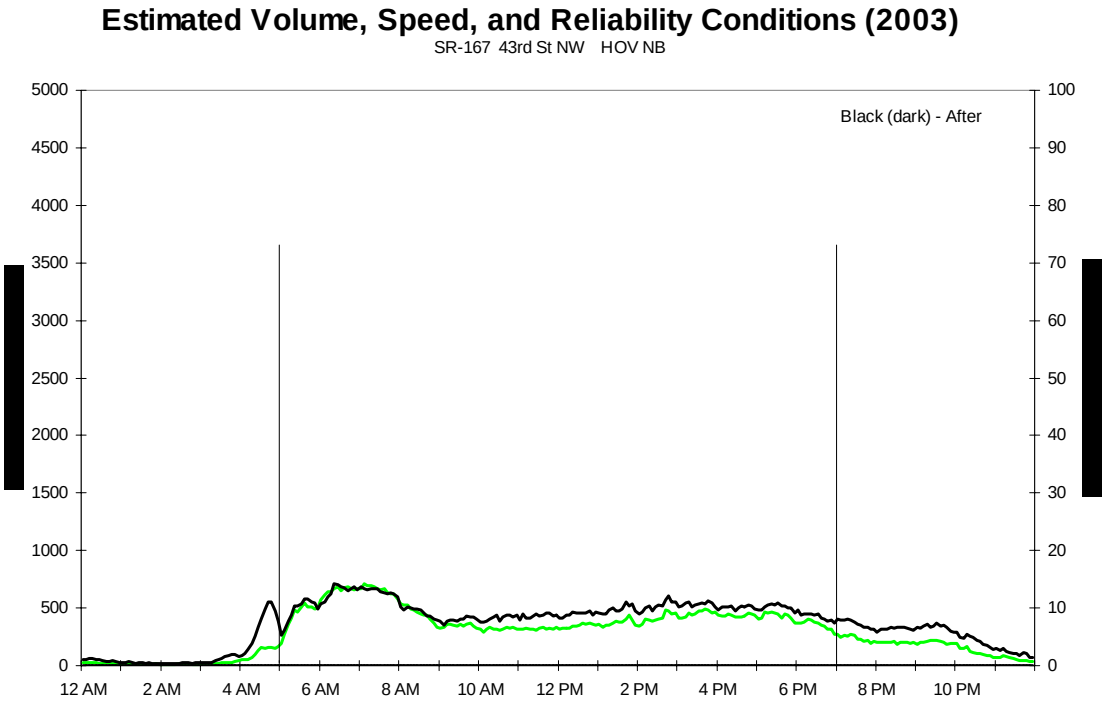

Figure 4.04. SR 167 NB near Auburn, HOV

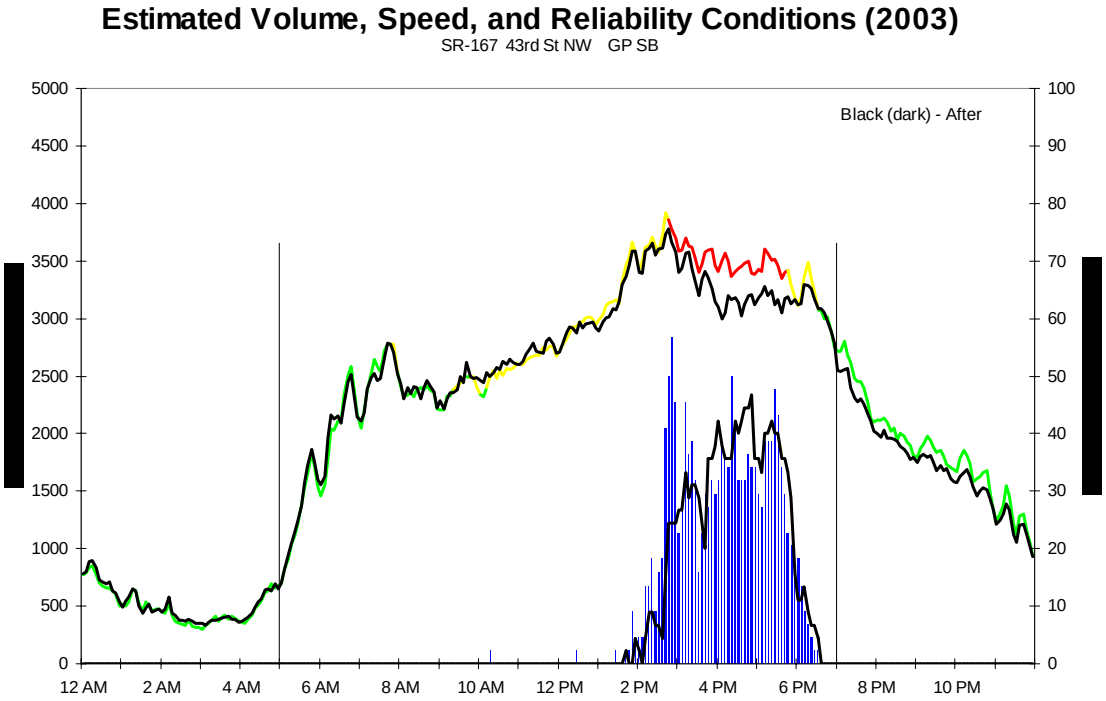

Figure 4.05. SR 167 SB near Auburn, GP

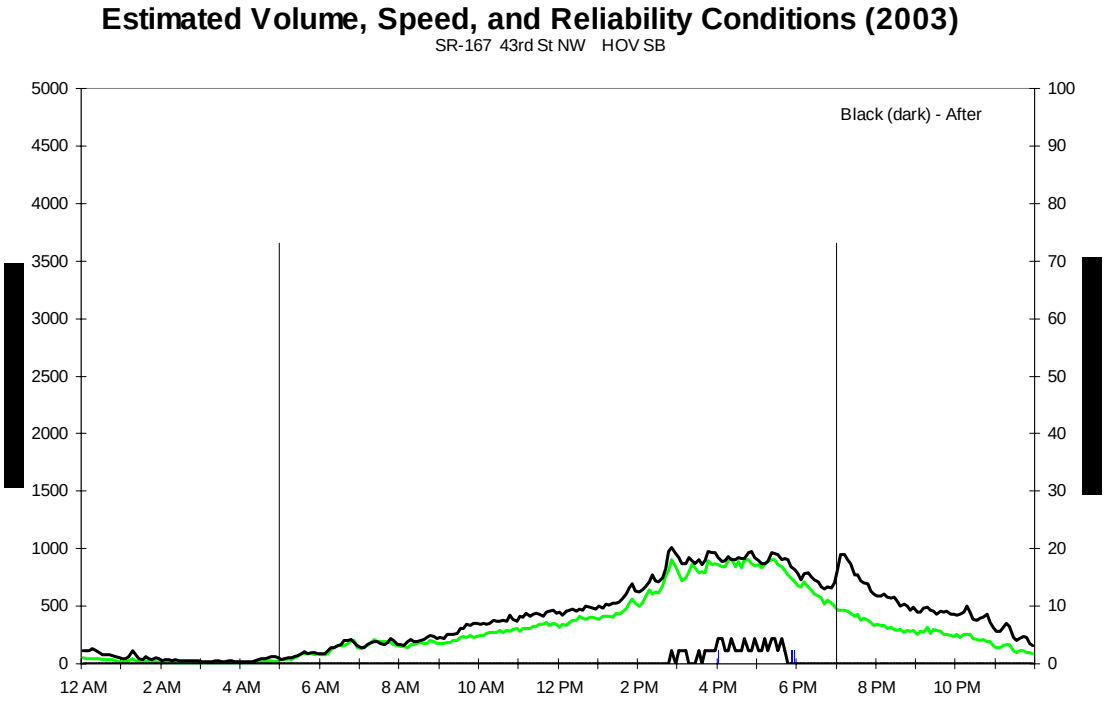

Figure 4.06. SR 167 SB near Auburn, HOV

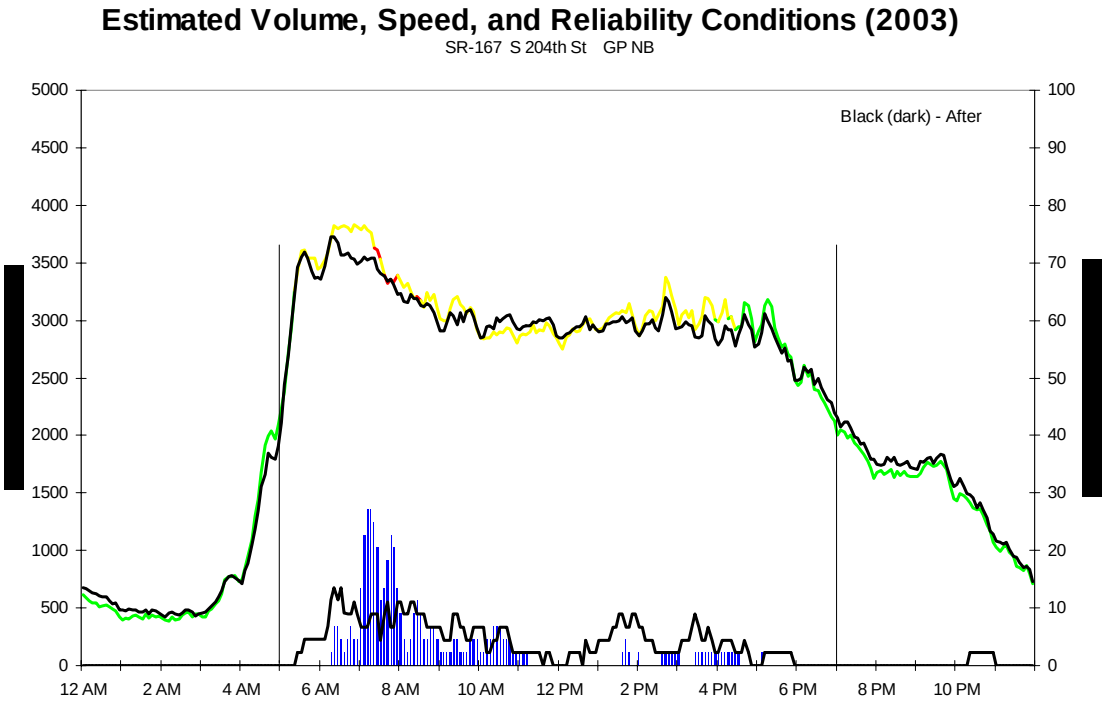

Figure 4.07. SR 167 NB near Renton, GP

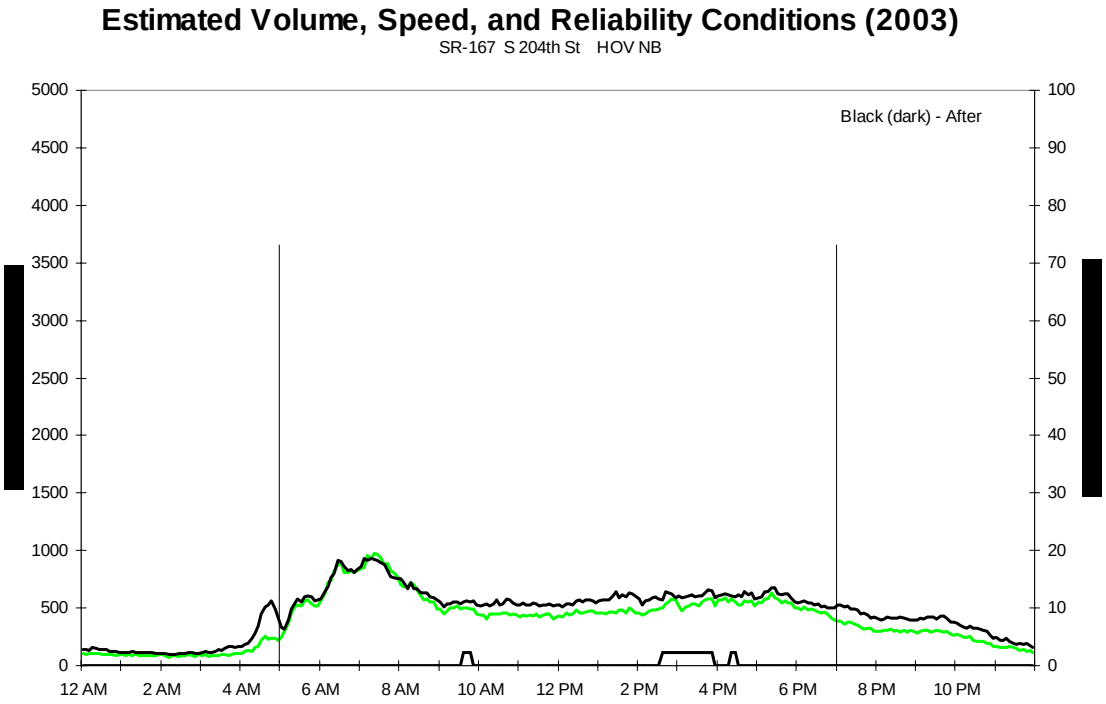

Figure 4.08. SR 167 NB near Renton, HOV

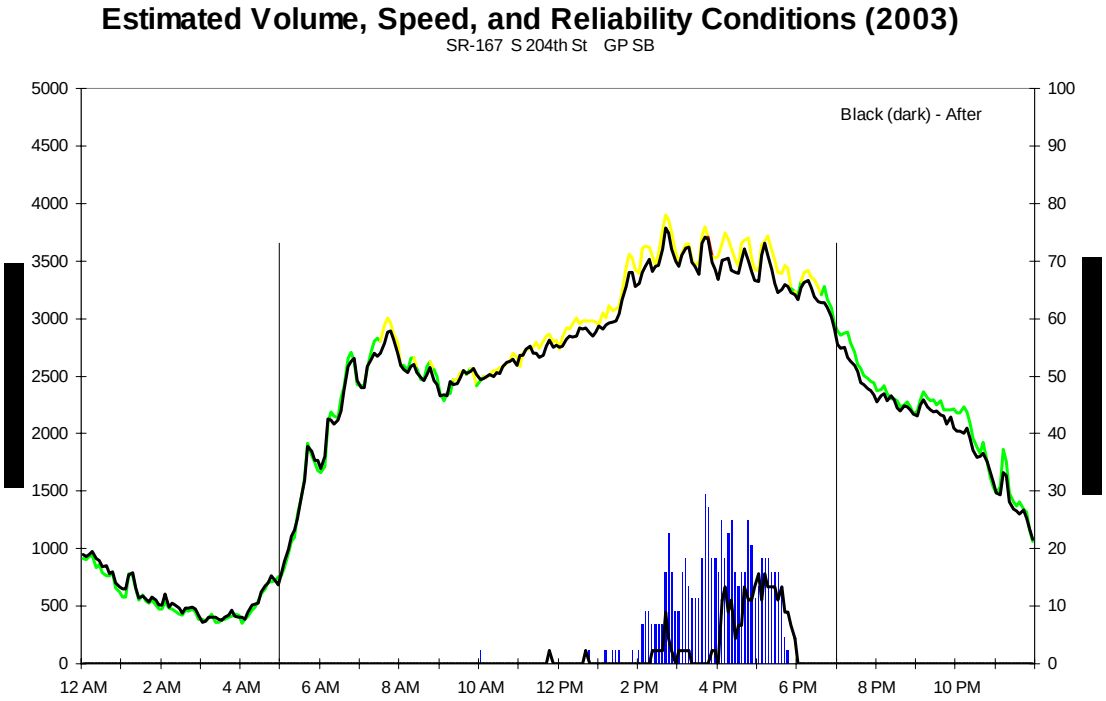

Figure 4.09. SR 167 SB near Renton, GP

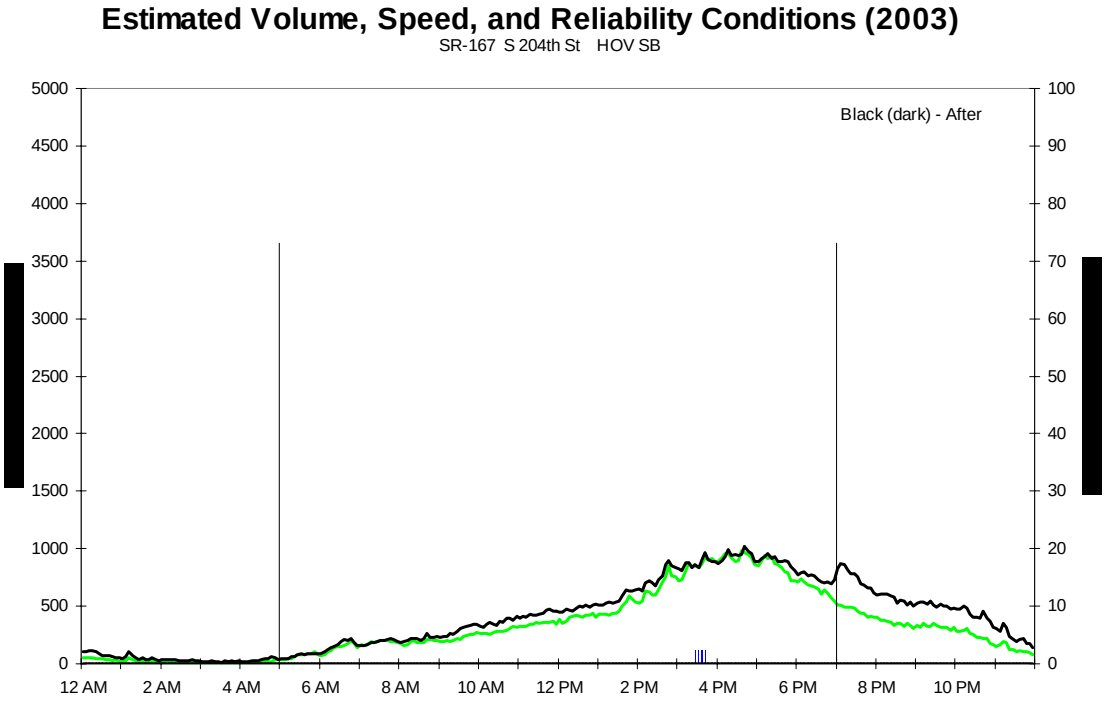

Figure 4.10. SR 167 SB near Renton, HOV

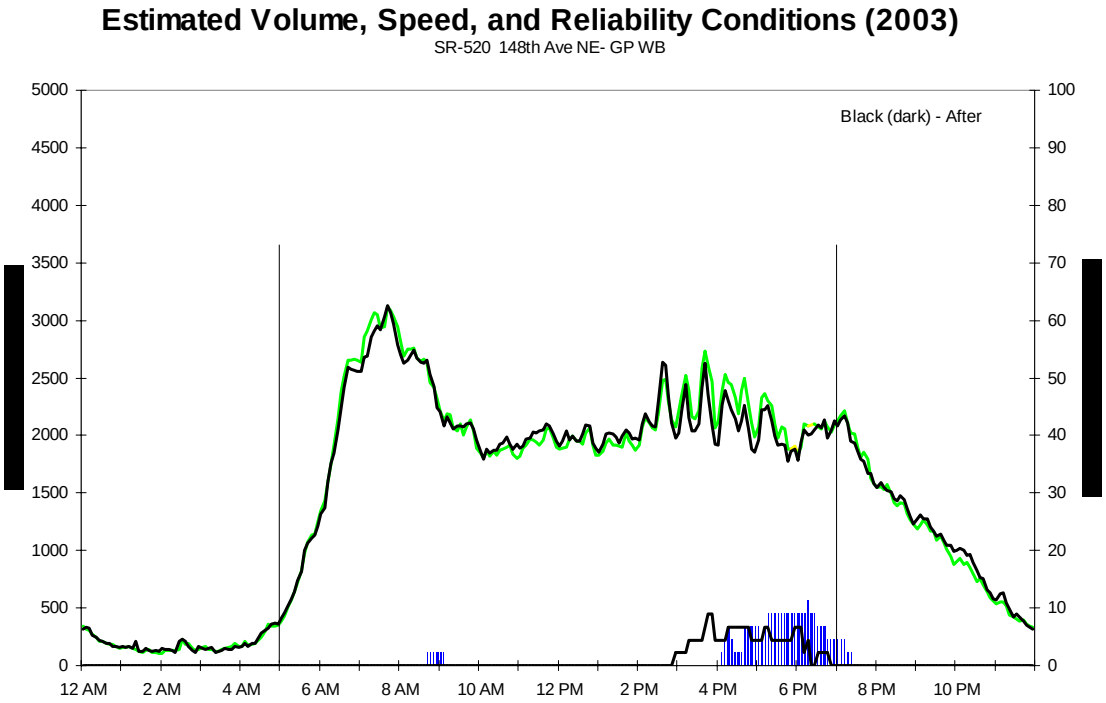

Figure 4.11. SR 520 WB near Redmond, GP

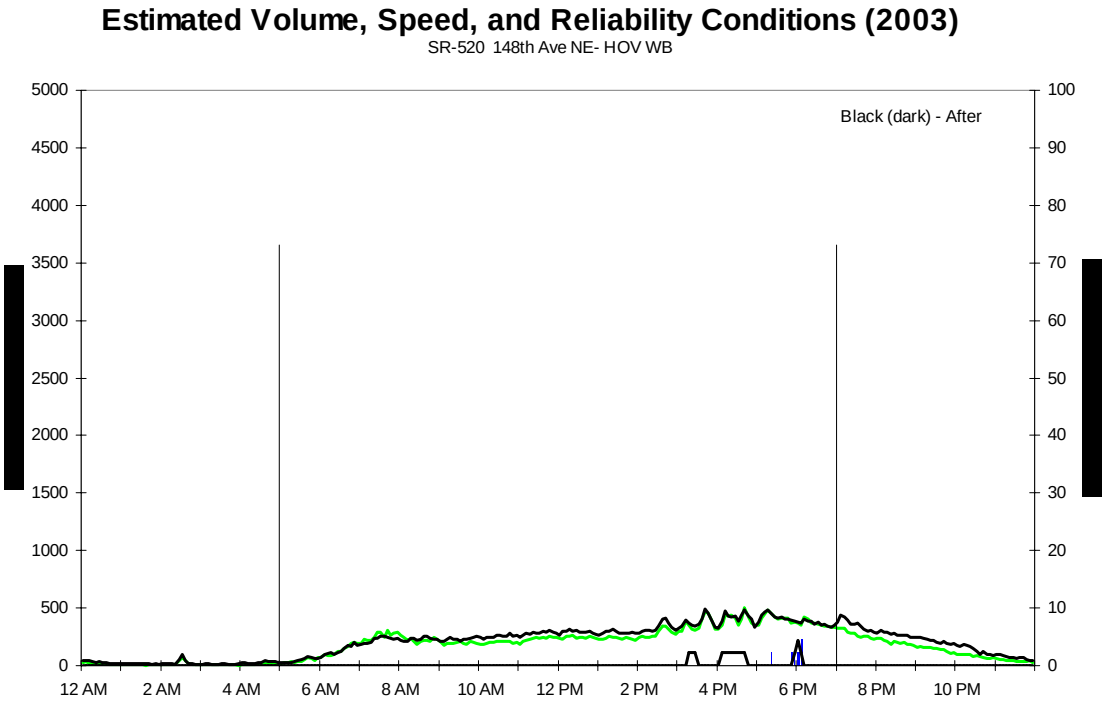

Figure 4.12. SR 520 WB near Redmond, HOV

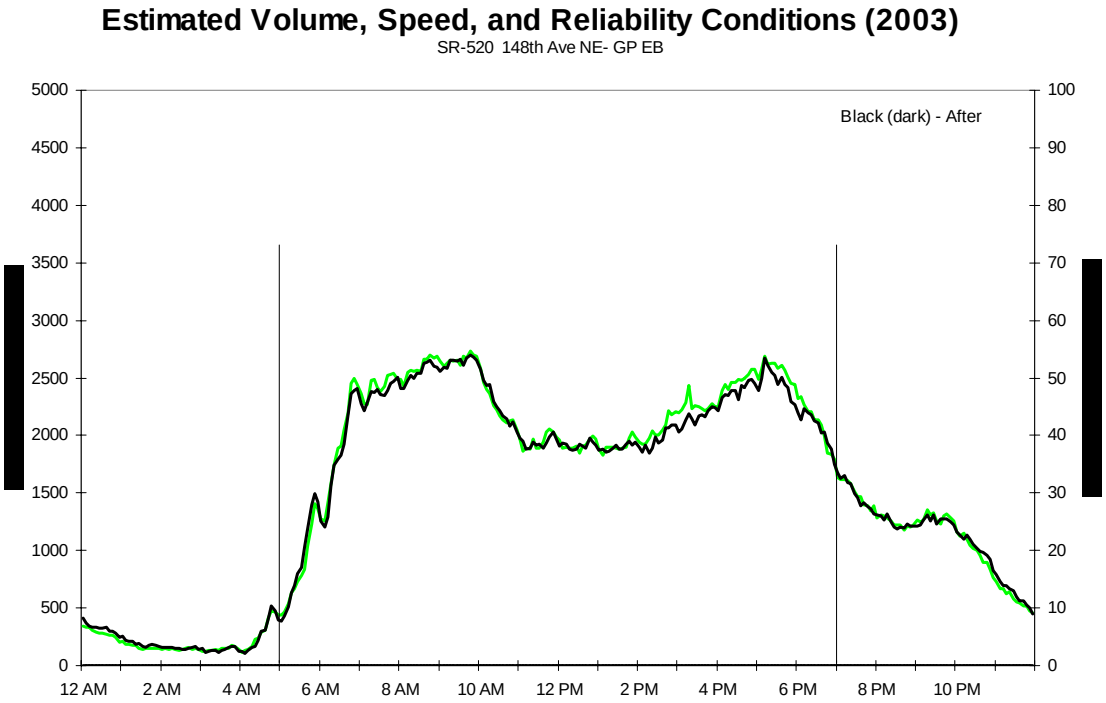

Figure 4.13. SR 520 EB near Redmond, GP

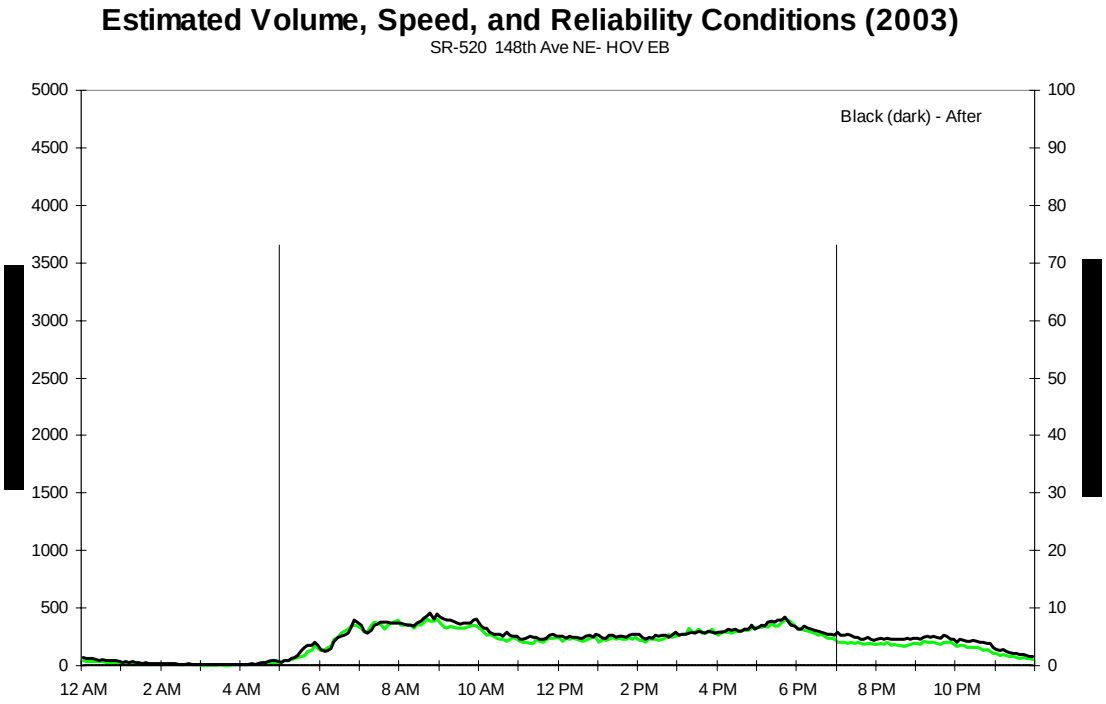

Figure 4.14. SR 520 EB near Redmond, HOV

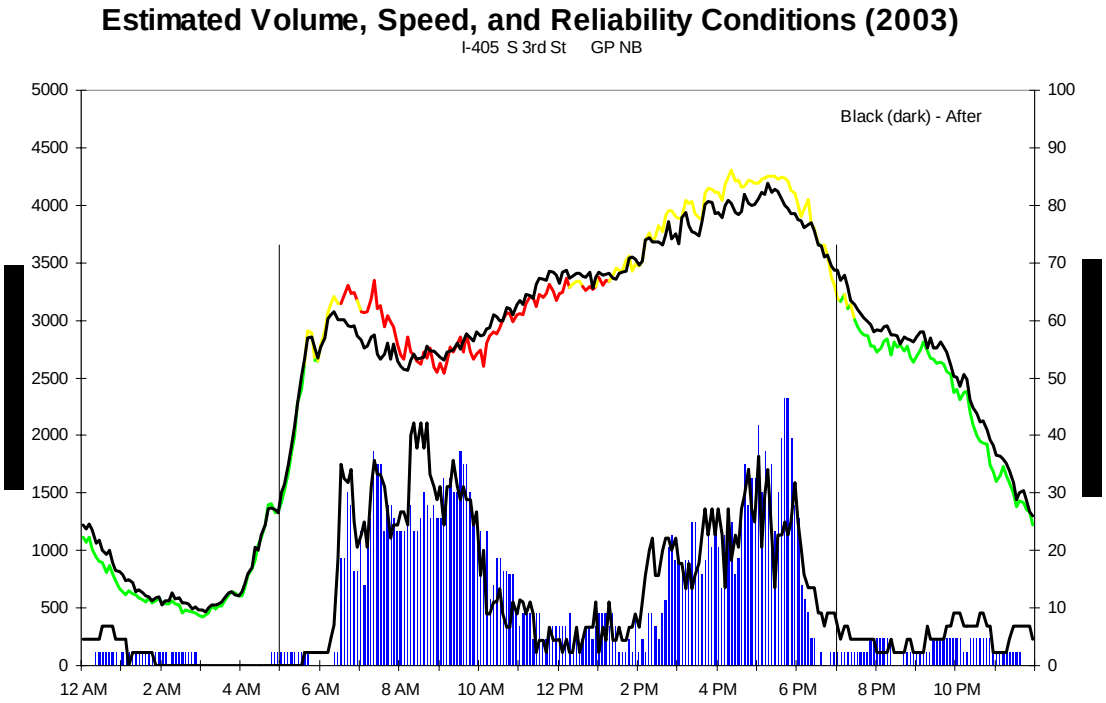

Figure 4.15. I-405 NB near Renton, GP

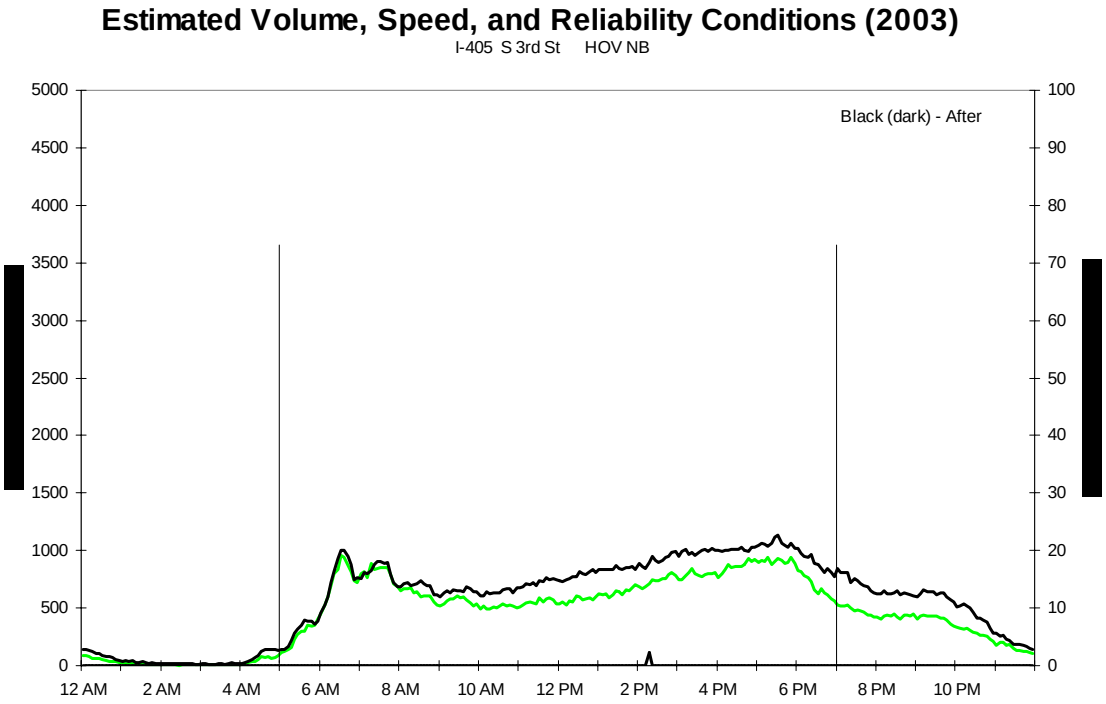

Figure 4.16. I-405 NB near Renton, HOV

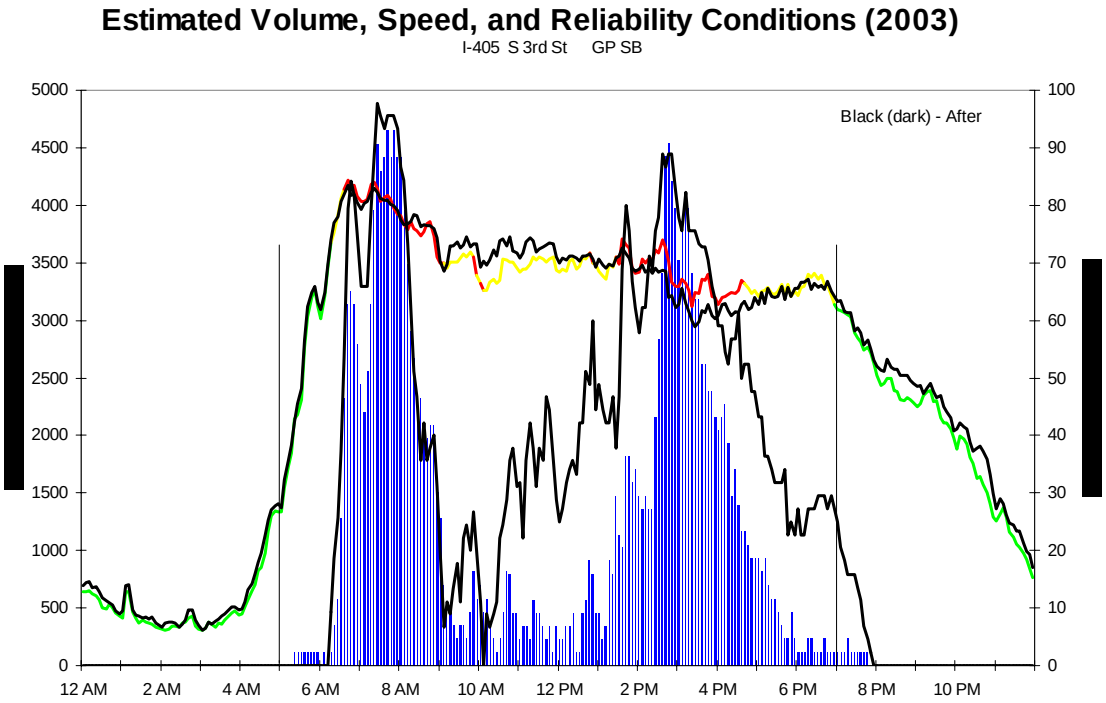

Figure 4.17. I-405 SB near Renton, GP

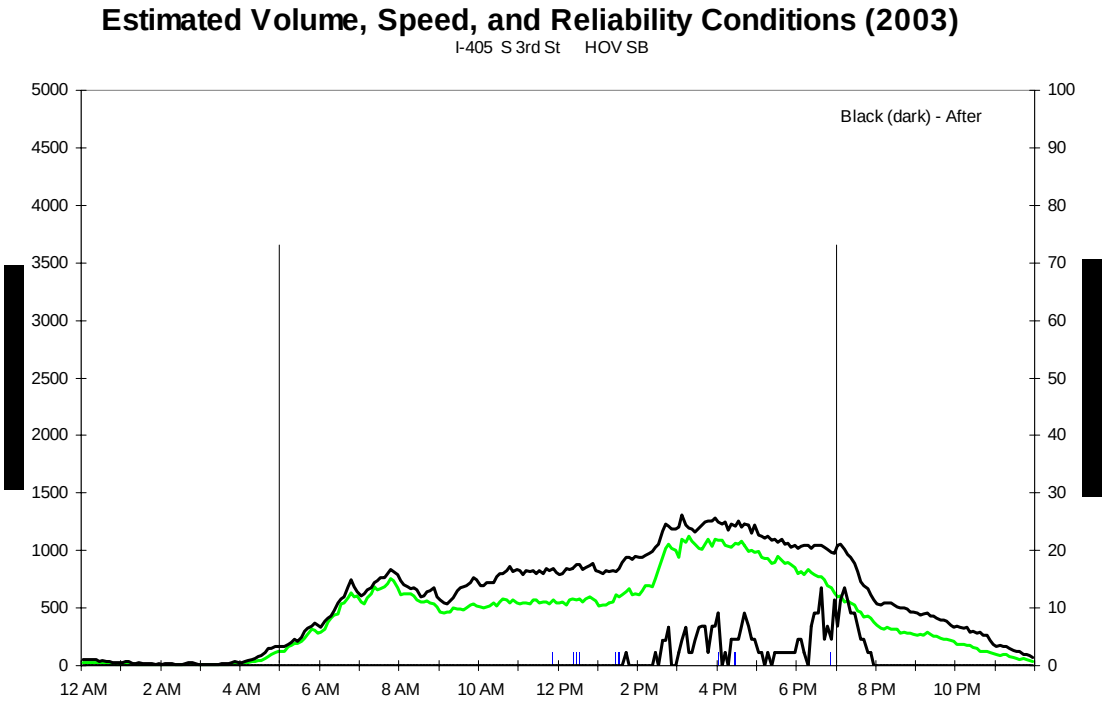

Figure 4.18. I-405 SB near Renton, HOV

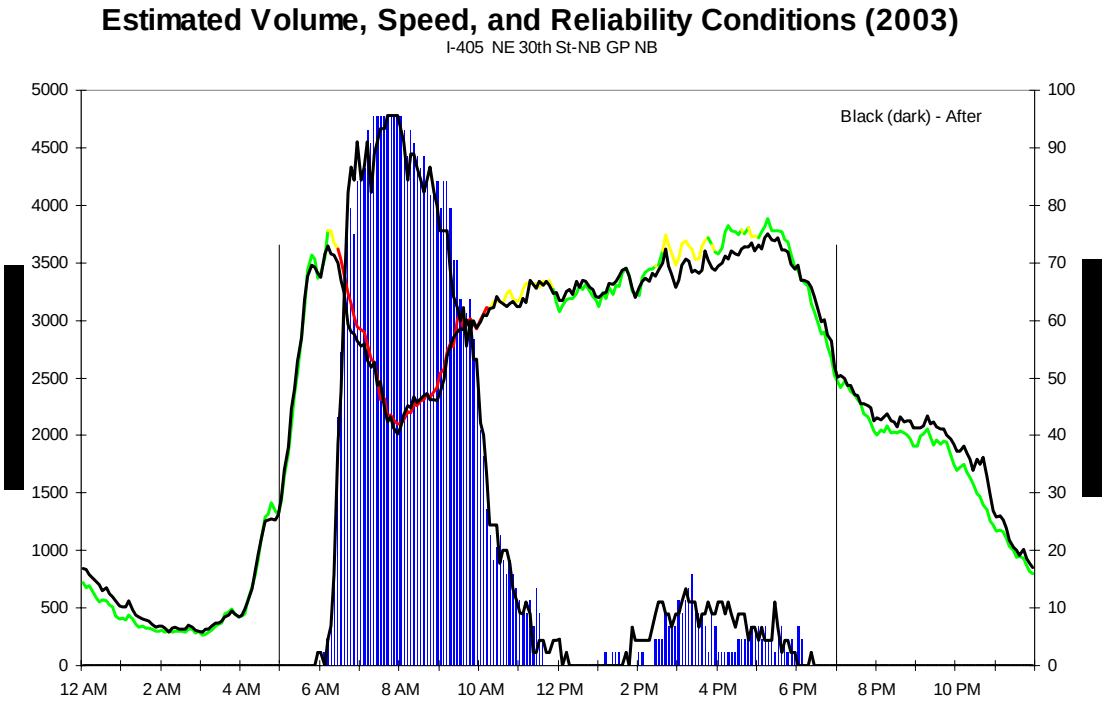

Figure 4.19. I-405 NB near Newcastle, GP

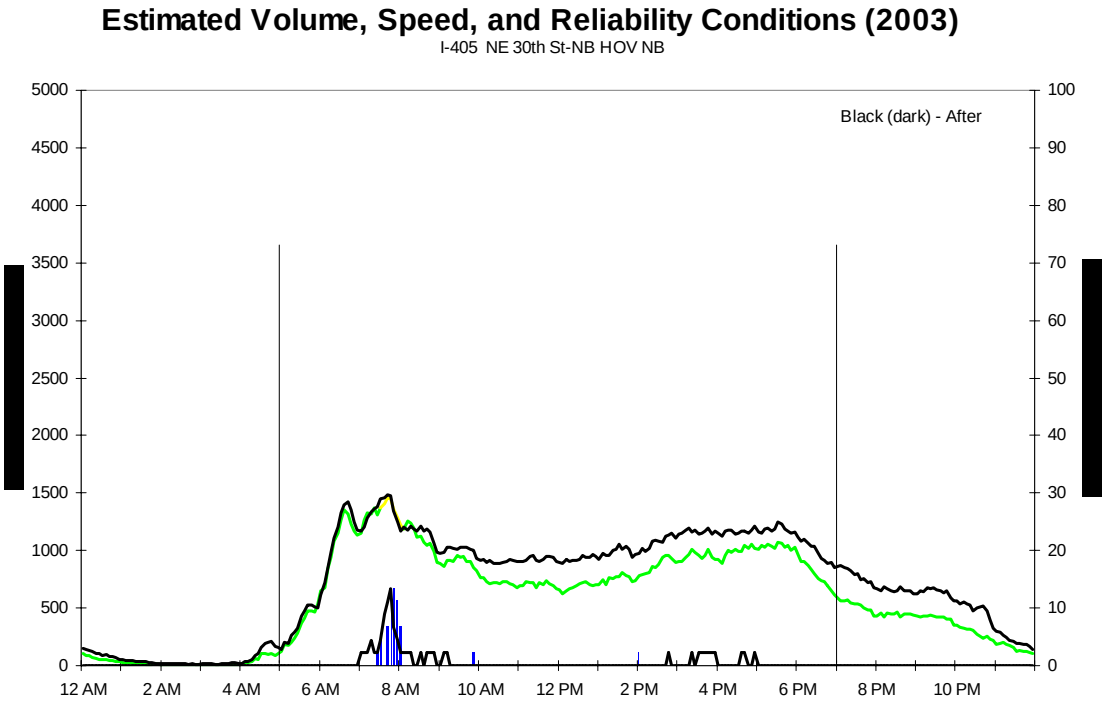

Figure 4.20. I-405 NB near Newcastle, HOV

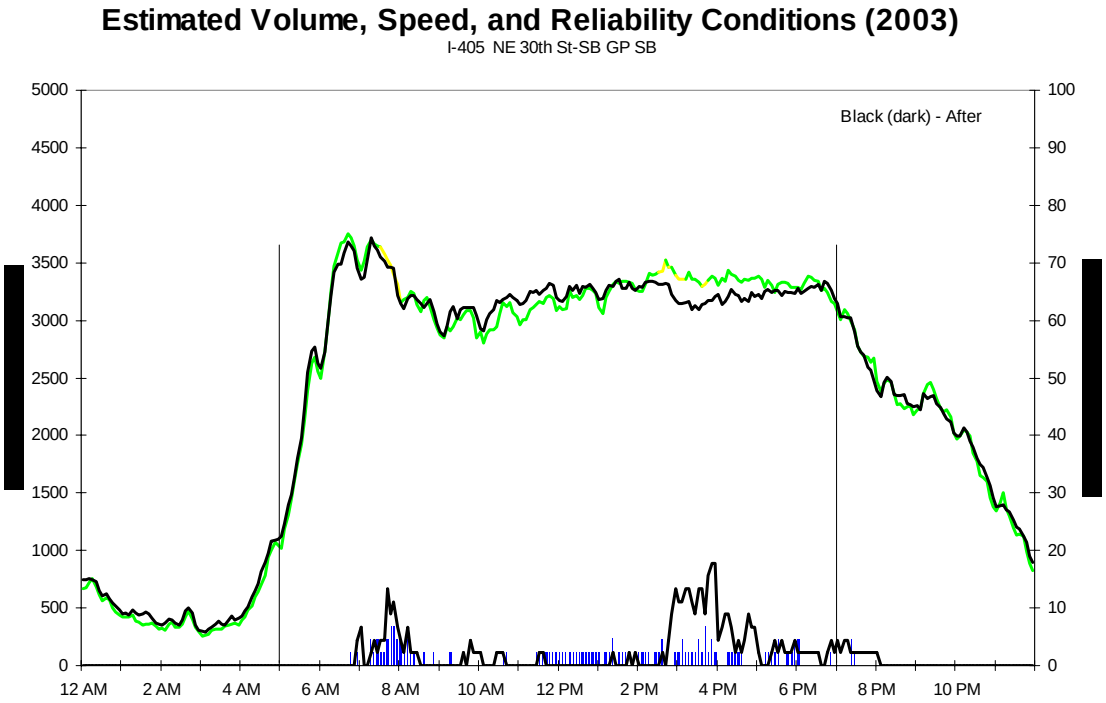

Figure 4.21. I-405 SB near Newcastle, GP

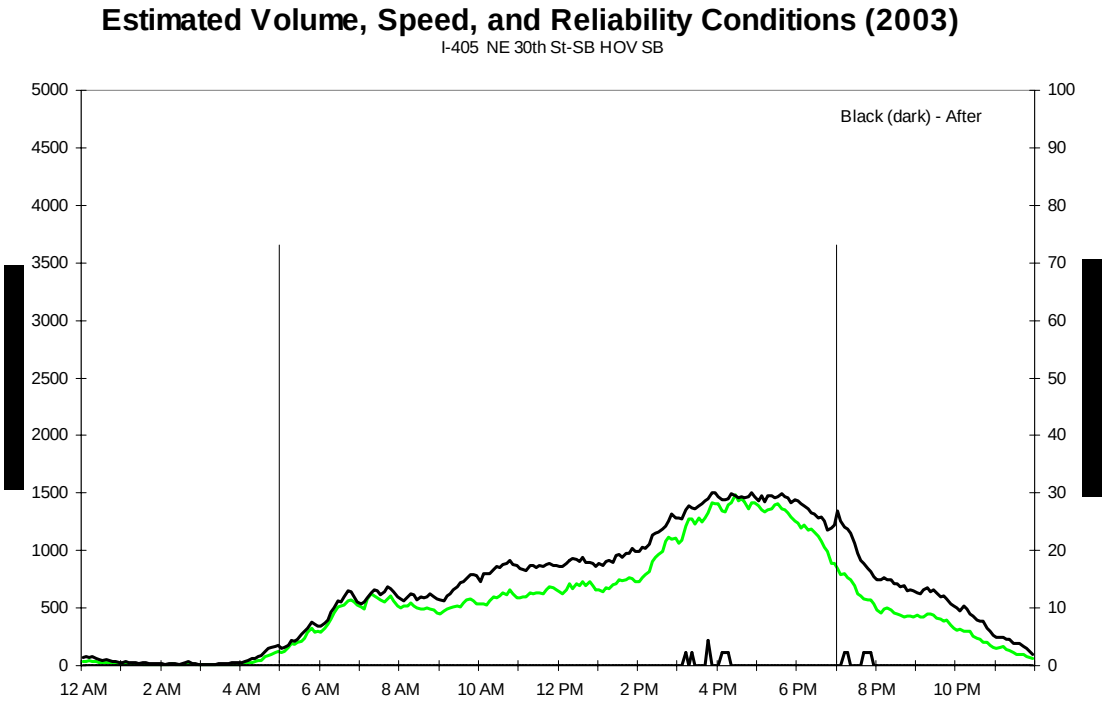

Figure 4.22. I-405 SB near Newcastle, HOV

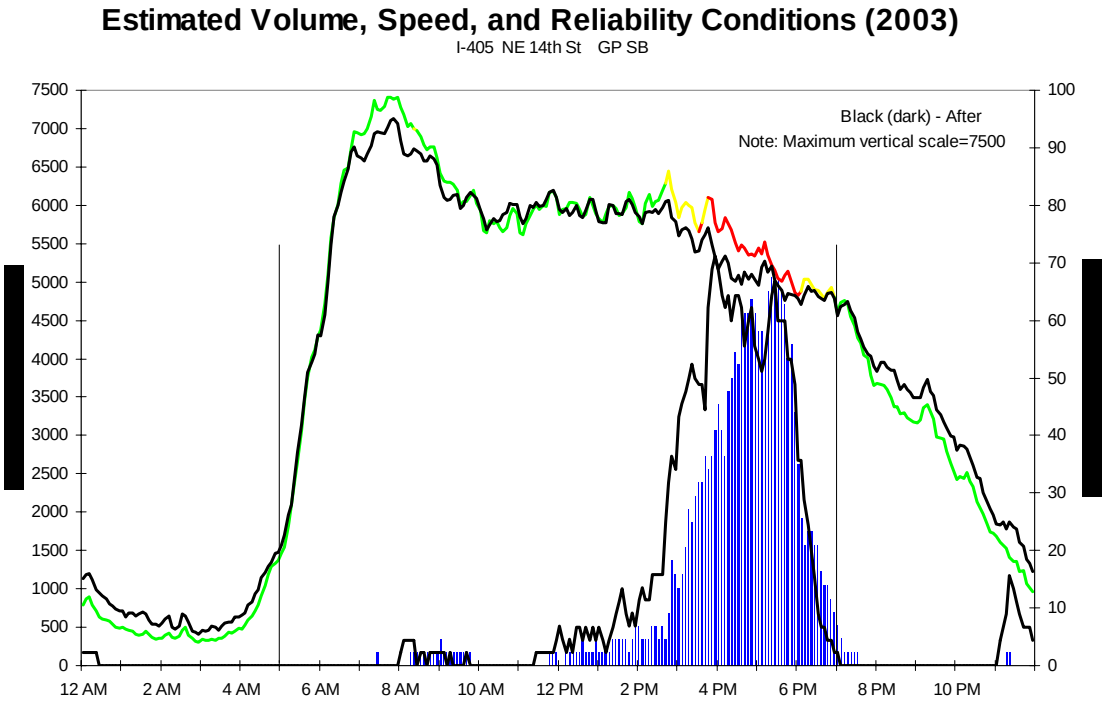

Figure 4.23. I-405 SB near Bellevue, GP

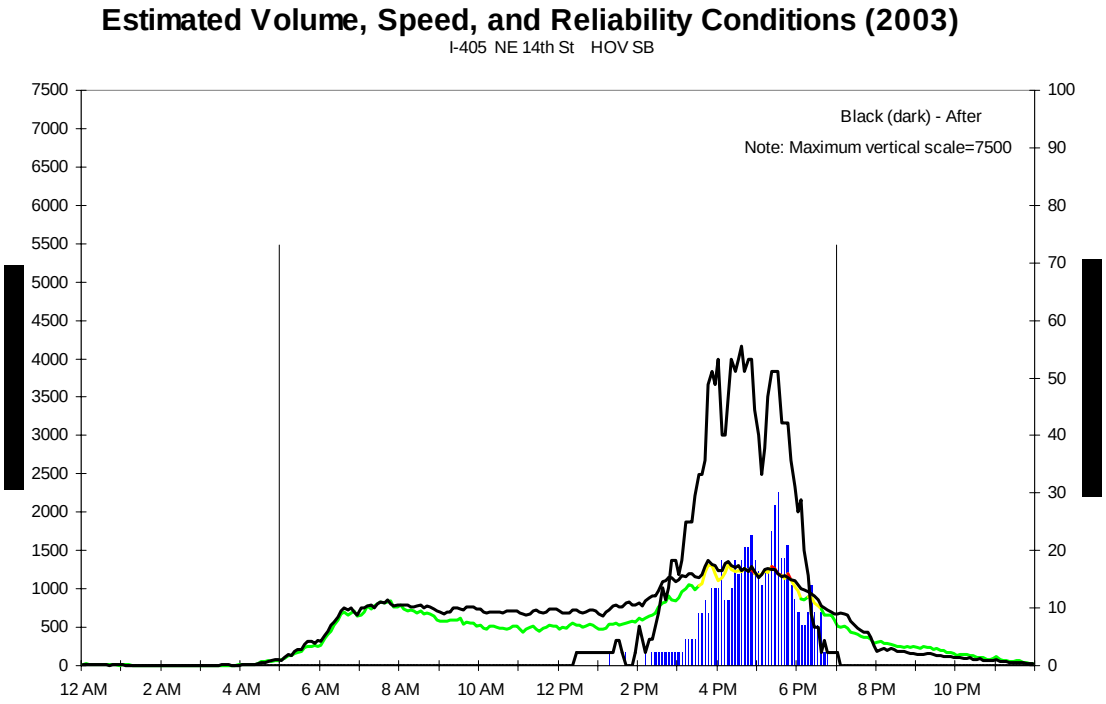

Figure 4.24. I-405 SB near Bellevue, HOV

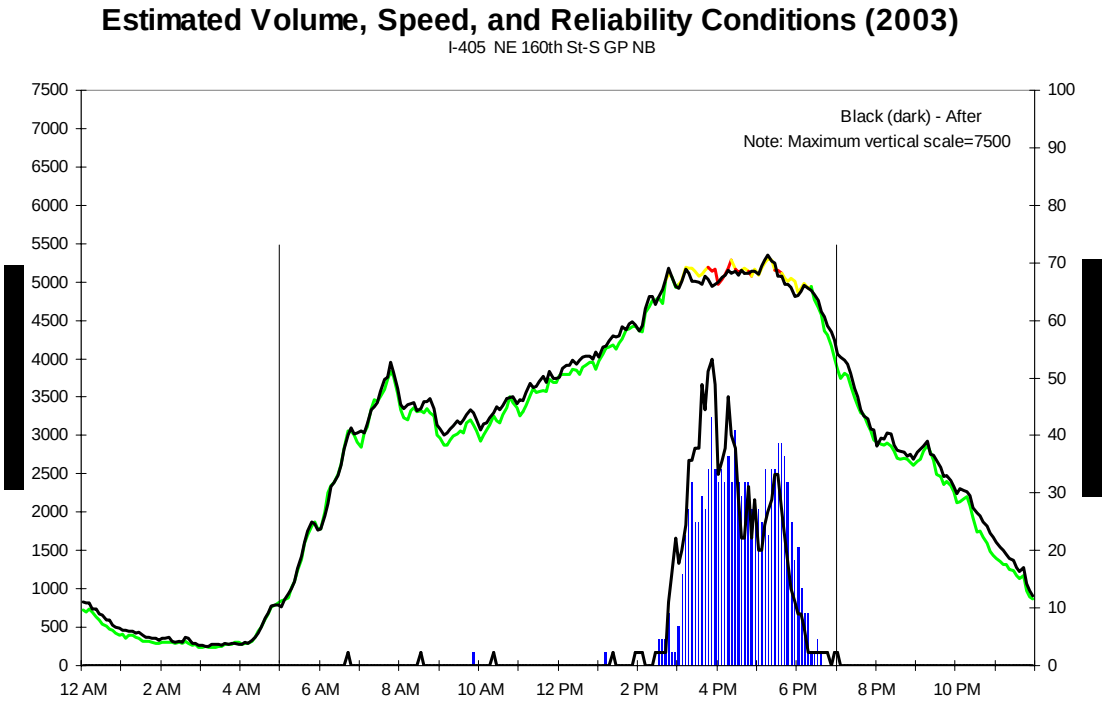

Figure 4.25. I-405 NB near Bothell, GP

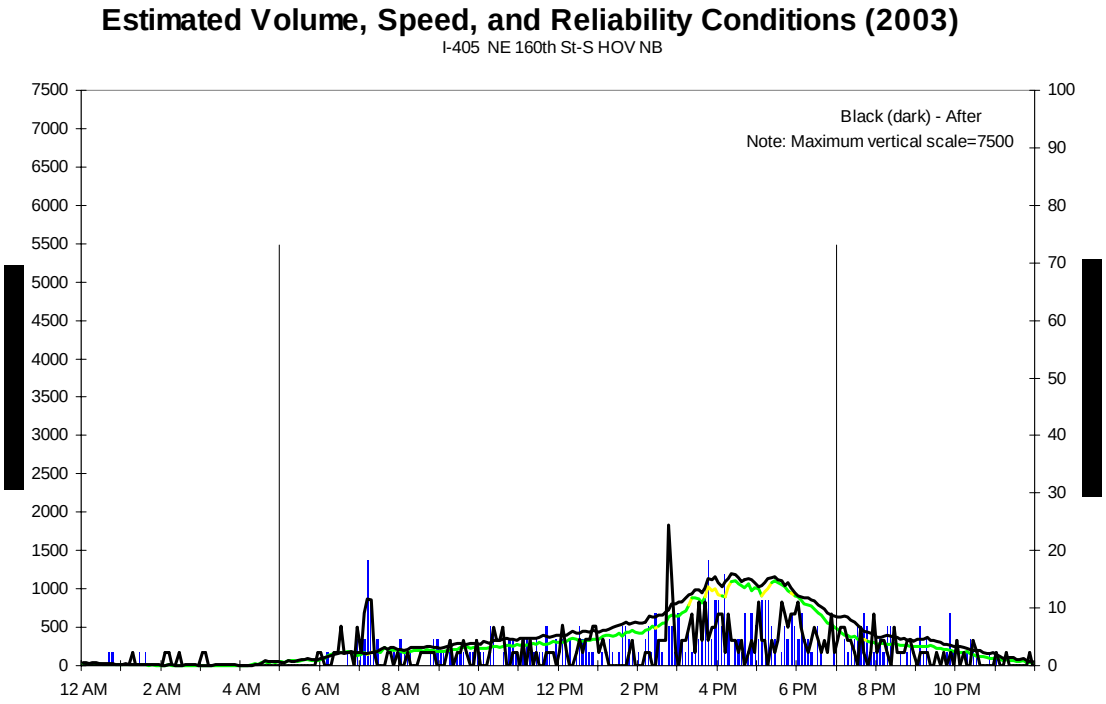

Figure 4.26. I-405 NB near Bothell, HOV

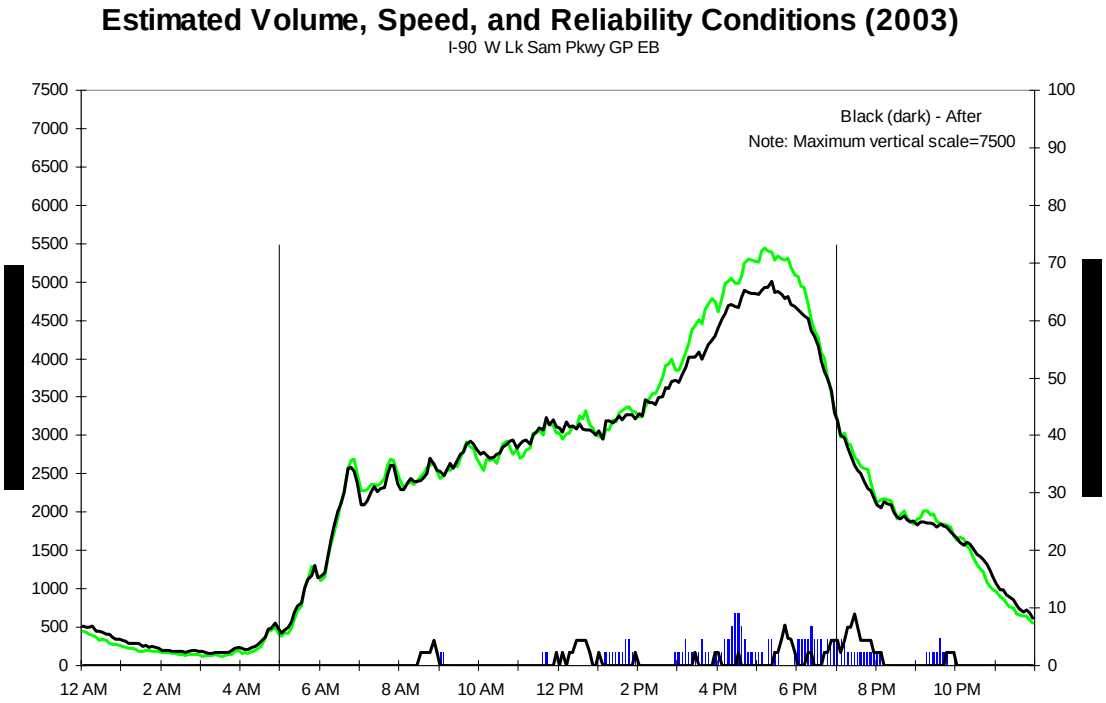

Figure 4.27. I-90 EB near Issaquah, GP

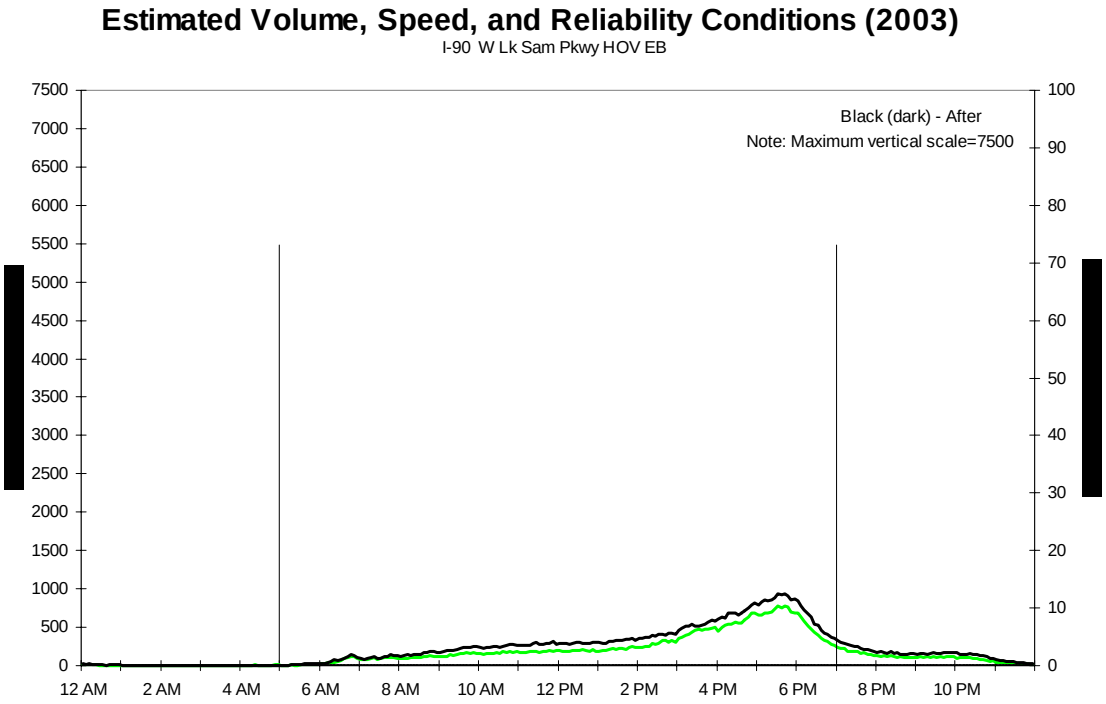

Figure 4.28. I-90 EB near Issaquah, HOV

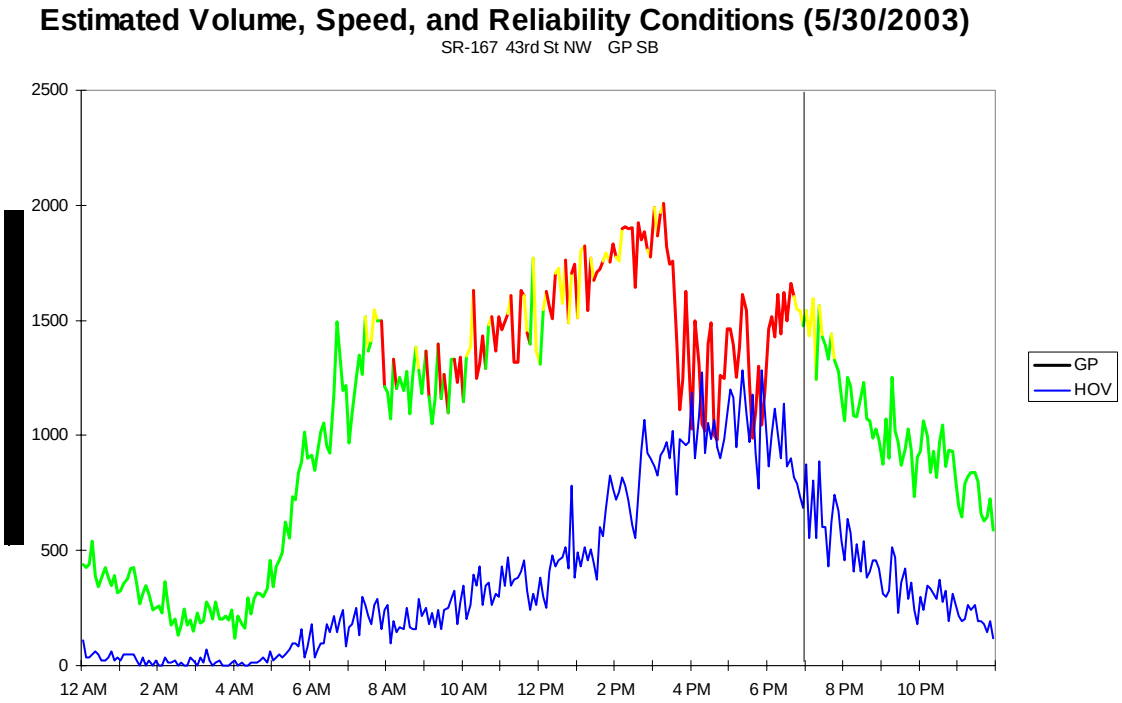

Figure 4.29. Performance Profile on SR 167 (May 30, 2003)

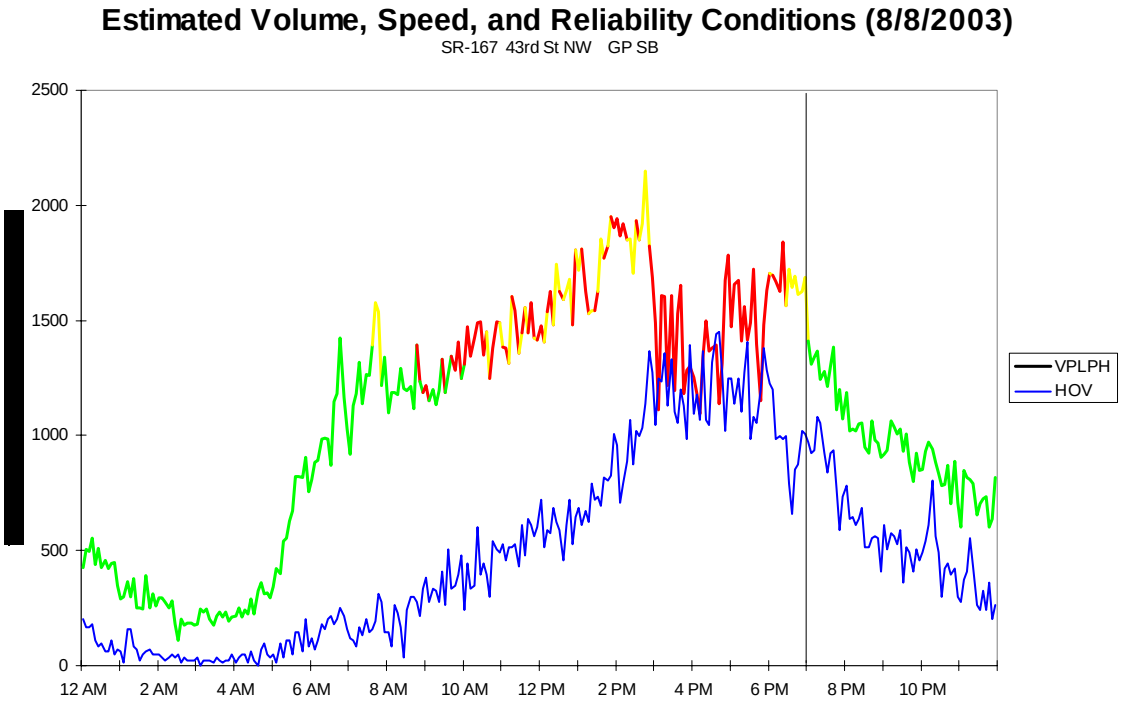

Figure 4.30. Performance Profile on SR 167 (August 8, 2003)

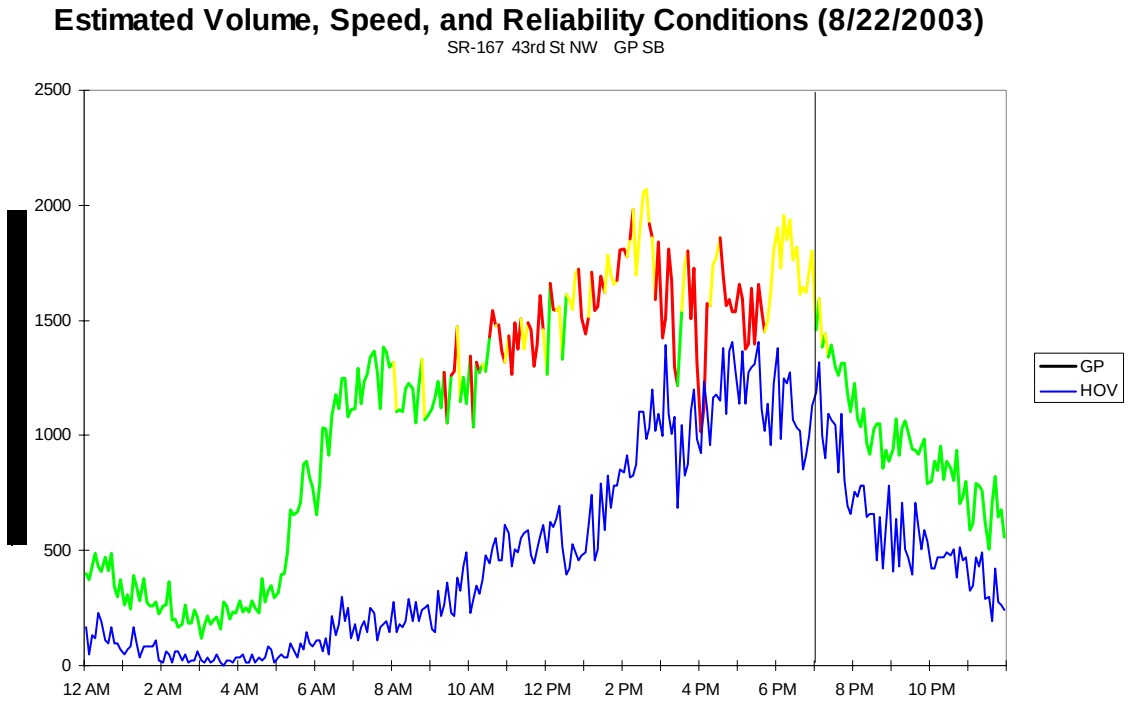

Figure 4.31. Performance Profile on SR 167 (August 22, 2003)

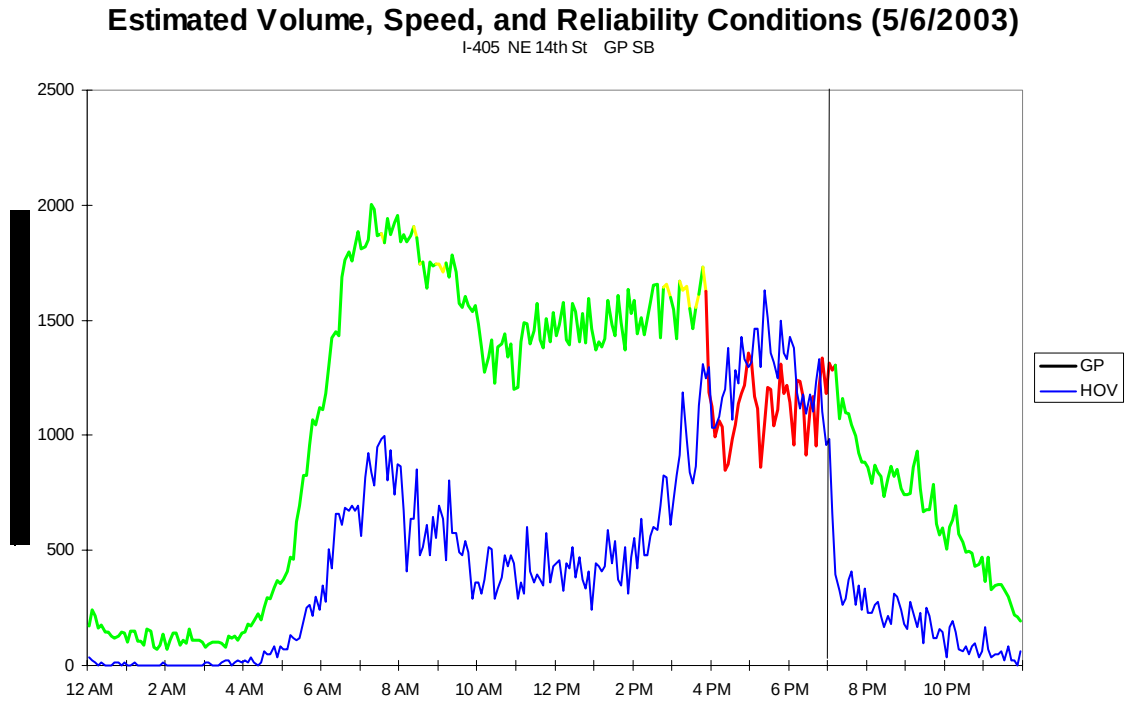

Figure 4.32. Performance Profile on I-405 (May 6, 2003)

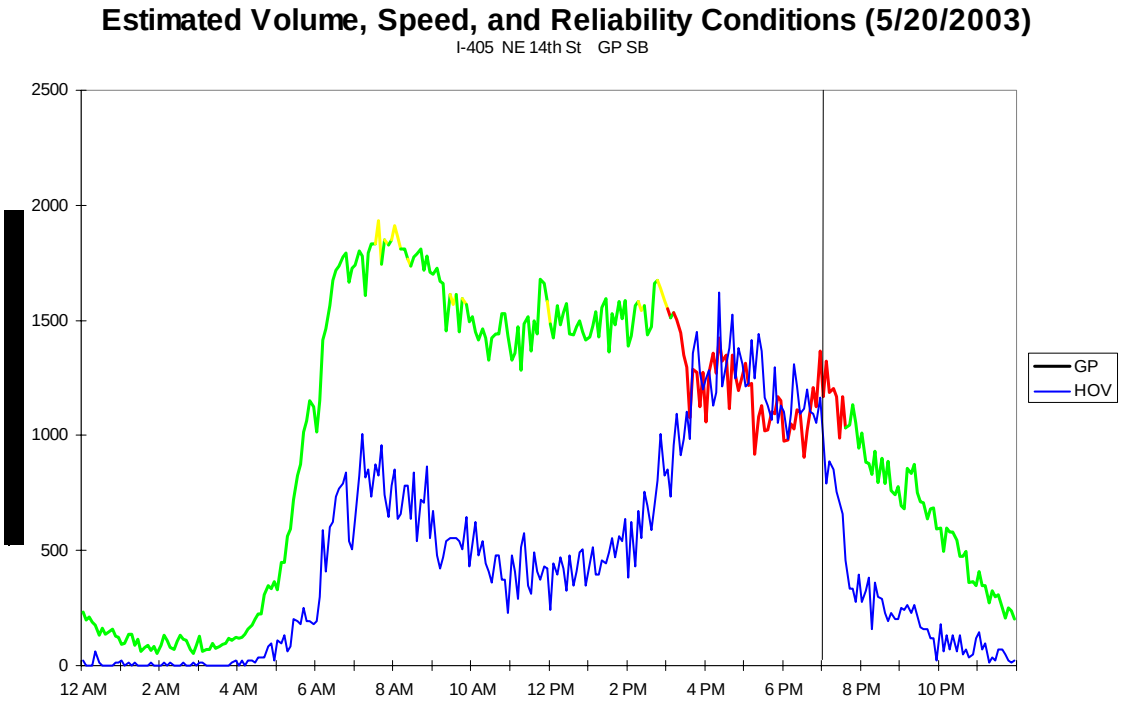

Figure 4.33. Performance Profile on I-405 (May 20, 2003)

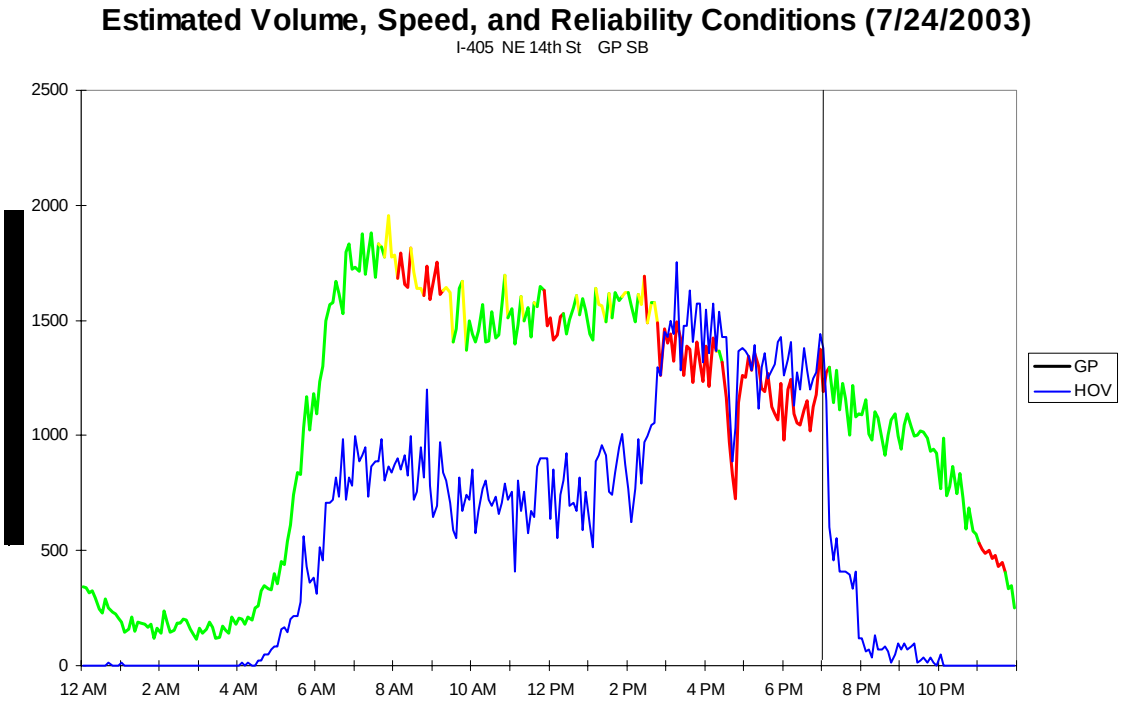

Figure 4.34. Performance Profile on I-405 (July 24, 2003)

SECTION 5
SUMMARY OF PRELIMINARY ANALYSES

The data processed thus far suggest that travelers appear to be aware of the revised hours of operation. The percentage and number of SOVs using the HOV lane at the start of the revised hours (7 PM) have increased, and the percentage of all traffic using the HOV lane after 7 PM has increased. In some locations, notably on SR 167, there is a significant increase in SOV usage of the HOV lane after 7 PM.

The results also suggest that the change in SOV violation rates in the HOV lane during the transition periods (6:45 PM to 7 PM, and after 5 AM) is generally not large: SOV violation rates are slightly higher during the PM transition period, and do not change significantly during the AM peak period.

Finally, traffic performance improvement after 7 PM as a result of the revised hours of operation cannot be conclusively determined from the initial data analyzed because congestion typically dissipates by that time on most days at most locations. As noted previously, locations on SR 167 have been observed to show the most significant use of the HOV lane by SOVs after 7 PM. However, even in the review of SR 167 data the before/after comparison of performance profiles does not show significant performance improvements. This appears to be because traffic performance is often significantly improving by 7 PM.

This is the first of three reports to be produced by this evaluation project. The preliminary results described in this paper are based on initial data collection only, and will be reviewed as additional data are collected in the coming months. The next report will be produced following the end of the first full year of operation.